INTRODUCTION TO
WORK STUDY
REVISED EDITION
The book describes as simply as possible the basic techniques of work study, giving examples of each. It is hoped that the book will be useful, not only for training courses, but also to spread a knowledge of the principles and scope of work study among managers, supervisors and workers' representatives in the enterprises to which trainees belong and thus ease their task in applying it. The book will serve as a convenient reference text for persons both inside and outside industry who are interested in work study problems.

So much can be done to raise productivity by well-tried methods easy to learn and relatively easy to apply that no attempt has been made to discuss the more refined and complex techniques; to do so would need to increase the size of the book and confuse the reader. There are many more advanced textbooks on the subject, a selection of which will be found in the book list at the end of this volume. In any case, these more refined techniques are the province of the expert, and their application should not be attempted without guidance.

In examining the causes of low productivity, and in general throughout the book, manufacturing industry has been discussed. This is because manufacturing industry in general represents the most complex case; nevertheless, it must be emphasised that work study can be applied equally profitably in service industries such as transport and in the administrative and clerical fields.

The book is divided into four parts.

The first part is entitled "Productivity and Work Study". It contains a brief description of the general problem of the causes of low productivity and the use of management techniques to eliminate them. This description has been included because it was felt that otherwise readers who were unfamiliar with the range of techniques at the disposal of those who direct and manage industry might gain the impression that work study is the cure for all productivity problems. Work study is one, but only one, of the management techniques by which productivity in an undertaking or other organisation can be raised and the costs of goods and services lowered. It is, however, a very important one, first because of its value in improving the use made of the resources of the undertaking and secondly because the use of work study techniques brings to light other weaknesses of organisation and operation. Both these characteristics of work study are discussed in detail in Chapter 4.

Two chapters are devoted to the environment—human and physical—in which work study is to be applied. The importance of having good human relations and good working conditions throughout the undertaking before attempting
to introduce work study cannot be overstressed. Work study, like other things, may be imposed in certain circumstances, but managerial techniques which are accepted by workers unwillingly and without understanding rarely work properly and are liable to break down completely after the circumstances change.

The second and third parts deal respectively with method study and work measurement, the two main techniques of work study.

The last part contains a number of appendices. A note on the use of this book as an aid to teaching will be found in Appendix 1. This note, which is based on experience in the field, gives suggested selections and breakdowns of chapters for two different types of courses. Obviously, there is no implication that the text or the arrangement of the subject should be followed slavishly. The great value of having teachers with practical experience of any subject is the vivid realism and the special knowledge which their experience enables them to put into their lectures. However, much of the material in this book is basic, and it is hoped that these notes may help those preparing lectures and courses by providing them with essential material to which they can add from their own stores of knowledge.

* * *

Writing a book on work study which can be used all over the world by persons trained in different countries with different systems and different terminologies is a difficult task. Any such book is bound to be a compromise and, like all compromises, there will be points of weakness.

The main problem in writing this book has been not what to include but what to omit. It has also been necessary to present some of the subject-matter in a rather over-simplified form and more dogmatically than the current state of knowledge and experience may warrant, or than would be done in a textbook intended for people more familiar with the subject.

It is not claimed that the techniques described here, especially in the chapters on work measurement, are necessarily the best available or that they represent the most up-to-date practices. They do, however, represent systems which have been widely and successfully applied in many parts of the world for a number of years. They have worked and they still do work, and they have contributed substantially to the attainment of high productivity in North America and Western Europe. It has been shown that they can contribute to increased productivity in the industrially less developed countries.

The reader cannot, of course, expect to be able to apply these techniques merely as a result of studying this book. It is not intended as a textbook but rather as an introduction, an aid to teaching and a reminder of what will be learned in systematic courses. Work study is a practical technique and it can only be learned practically under the guidance of experienced teachers. The principles underlying it are
PREFACE TO THE SECOND EDITION

The original version of this book was written primarily for persons attending courses in work study in management development and productivity centres in developing countries to which I.L.O. technical co-operation missions were attached and to provide basic teaching material for members of these missions and for the national staffs of the centres. Since it first appeared in definitive form in 1957 over 130,000 copies have been sold or distributed in English, French and Spanish, the three working languages of the I.L.O., and it has been translated into a number of other languages, including Japanese and Korean. Although intended for use in developing countries, the book has become the standard introductory textbook in teaching institutions in certain industrially advanced countries, notably the United Kingdom.

As its title suggests, the book was intended as an introduction to the subject and not as an exhaustive textbook. Its aim is to provide trainees and teachers with the basic elements on which they could develop their knowledge of more advanced practices and special applications. As a matter of policy it was confined to the basic elements of work study alone and did not embrace such questions as incentive schemes with which work study, especially work measurement, is usually associated. Nor did it attempt to deal with advanced work study techniques. It was written in the first place because an examination of current literature in the work study field showed that no simple and comprehensive handbook suitable for providing a basic introduction existed. The unexpected success of the book seems to have justified the view that it has filled a need.

More than ten years have passed since the first impression appeared and usage in many countries has brought to light shortcomings in the original text. There have also been certain developments which, it is felt, should be dealt with or treated more fully. The preparation of the second edition has been made the occasion for a complete overhaul of the text, especially of Part III, Work Measurement, which has been radically rewritten. However, the original intention has been adhered to and advanced techniques or special applications are mentioned but not treated in depth.

When the first edition was written there was no uniform glossary of work study terms or system of application in any English-speaking country, although standard systems existed through the national institutions in France and Germany. It was therefore decided to adopt a terminology and systems of method study and work measurement which, while based on practice in the United Kingdom, were sufficiently generally applicable and accepted as to provide the basic grounding which
would enable students to understand and subsequently adopt any other system which they might be required to use. The result, inevitably, was a compromise which left strong exponents of particular systems somewhat unsatisfied, but which seems to have served its purpose.

In considering what modifications should be made to the second edition, the authors took account of the fact that in 1959 the British Standards Institution published the British Standard Glossary of Terms in Work Study (B.S. 3138). This Glossary was the result of several years work by a Committee of the Institution widely representative of practitioners of different systems of work study, the principal professional institutions concerned, employers' organisations and the Trades Union Congress, and represents the outcome of their collective thinking. It is by far the most comprehensive attempt to rationalise and standardise work study terminology and practice which has yet been achieved. Although it is recognised that, as an international agency, the I.L.O. has the duty of presenting various national practices as far as possible, it was felt that it was preferable, in this case, to adopt a wholly consistent system rather than to attempt a compromise which might have the effect of merely confusing readers without offering corresponding advantages.

Readers familiar with the original version of this book will find that there is available which have been in consequence many changes of substance, particularly in the part of the book which deals with work measurement. The adoption of the B.S. rating scale, the 0–100 scale, in place of the 100–133 scale used formerly has entailed radical alterations in the presentation of the chapters on time study and has sometimes involved the assigning of quite different meanings to old and familiar terms. Readers who are not familiar with the newer terminology will find it advantageous to study first Appendix 5, which reproduces a number of terms used in the British Standard Glossary. A folder lists the main changes in each chapter. It is hoped that this will be of service to teachers who have been using the earlier version, perhaps for years, and who will now find that their students are working from the revised edition. The folder has been perforated to enable the passage relating to each chapter to be detached and affixed to the title page of the chapter, if desired.

Metric measurements have been adopted throughout this edition, so that many of the charts and illustrations, while essentially similar to those in the original version, have been changed in detail. Twenty-two fresh figures have been added, bringing the total number of illustrations to 97.

The original edition of the book was written by Mr. C.R. Wynne-Roberts of the Economic Division, I.L.O., now Chief of the Human Resources Department, in collaboration with Mr. E.J. Riches, Economic Adviser, now Treasurer and Comptroller to the I.L.O.
comparatively simple, and, once they are properly understood, practices can be adapted to suit circumstances; but the principles must be mastered first. It is hoped that this book will make the understanding of these principles easier.

The International Labour Office is grateful to the many people who sent in suggestions and comments on the text. In particular, special thanks are due to Messrs. Hans Fahlström, L. P. Ferney, Hy Fish, C. L. M. Kerkhoven, J. B. Shearer and Seymour Tilles, members of I.L.O. productivity missions who took the trouble to prepare very detailed and valuable commentaries, to Mr. H. N. Nanjundiah of the Indian Productivity Centre and to Dr. Mohamed Amin of the Egyptian Productivity and Vocational Training Centre. Acknowledgement must be made for the valuable contributions and criticisms of Dr. T. U. Matthew, formerly Lucas Professor of Engineering Production, Birmingham University¹, Mr. F. de P. Hanika of the Royal Technical College, Glasgow, and Mr. Winston M. Rodgers of the United Kingdom Department of Scientific and Industrial Research. Thanks are also due to the Work Study Department of Imperial Chemical Industries Ltd. for its extremely detailed suggestions and to all other persons who contributed comments or information on specific items in the book.

¹ Now deceased.
This revised edition has been prepared for the International Labour Office by Mr. R. L. Mitchell, who, as Chief of I.L.O. management development missions in India and Turkey, made extensive use of the original version in teaching work study in association with the original author. In making this revision he has had the benefit throughout of the advice and collaboration of Mr. J. B. Shearer of the Management Development Branch, I.L.O., who has himself had extensive experience in using the book in the field.
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PART ONE

PRODUCTIVITY
AND
WORK STUDY
PRODUCTIVITY
AND THE
STANDARD OF LIVING

1. THE STANDARD OF LIVING

The standard of living of any man is the extent to which he is able to provide himself and his family with the things that are necessary for sustaining and enjoying life.

The standard of living of the representative man or family in the different nations or communities of the world varies greatly. A poor man in the United States and in some countries of Western Europe would be a rich man in other countries. The countries in which the ordinary man and his family are able to enjoy not only all the necessities for a healthy life but also many things which might be classed as luxuries, are still too few. In too many parts of the world the ordinary man is hardly able to obtain even the necessary things. He and his family are rarely able completely to satisfy their hunger, to clothe themselves properly or to enjoy housing conditions in which they can be comfortable and healthy.
2. REQUIREMENTS FOR A MINIMUM SATISFACTORY
STANDARD OF LIVING

What are the necessities of a minimum decent standard of living? Principally, they are—

- **FOOD**
  enough food every day to replace the energy used in living and working;

- **CLOTHING**
  enough clothes to permit bodily cleanliness and afford protection from the weather;

- **HOUSING**
  housing of a standard to give protection under healthy conditions; and

- **HYGIENE**
  sanitation and medical care to give protection against disease and treatment in illness.

To these may be added—

- **SECURITY**
  security against robbery or violence, against loss of the opportunity to work, against poverty due to illness or old age; and

- **EDUCATION**
  education to enable every man, woman and child to develop to the full their talents and abilities.

Food, clothing and housing are generally things which a man has to obtain for himself. In order to have them he must pay for them, either in money or work. Hygiene, security and education are generally matters for governments and other public authorities. The services of public authorities have to be paid for, generally by individual citizens, so each man must earn enough to pay his contribution to the common services as well as to support himself and his family.

Each nation or community must, in the long run, be self-supporting. The standard of living achieved will be that which the representative citizen is able to achieve through his own efforts and those of all his fellow-citizens.

The greater the amount of goods and services produced in any community, the higher its average standard of living will be.

There are two main ways of increasing the amount of goods and services produced. One is to increase employment; the other is to increase productivity.
If in any community there are men and women who are able to work and who want work but who are unable to find work, or who are able to find only part-time work, the output of goods and services can be increased if full-time productive work can be provided for them, i.e. if employment can be increased. Whenever there is unemployment or underemployment efforts to increase employment are very important and should go hand in hand with efforts to increase the productivity of those who are already employed. But it is with the latter task that we are here concerned.

We can have—

- more and cheaper **food** by increasing the productivity of **agriculture**;
- more and cheaper **clothing** and **housing** by increasing the productivity of **industry**;
- more **hygiene**, **security** and **education** by increasing all productivity and earning power, leaving more from which to pay for them.

### 3. WHAT IS PRODUCTIVITY?

It may be defined as follows:

Productivity is the ratio between output and input.

This definition applies in an enterprise, an industry or an economy as a whole.

Put in simpler terms, productivity, in the sense in which the word is used here, is nothing more than the arithmetical ratio between the amount produced and the amount of any resources used in the course of production. These resources may be—

- **LAND**
- **MATERIALS**
- **PLANT, MACHINES AND TOOLS**
- **THE SERVICES OF MEN**

or, as is generally the case, a combination of all four.

We may find that the productivity of labour, land, materials or machines in any establishment, industry or country has increased, but the bare fact does not in itself tell us anything about the reasons why it has increased. An increase in the productivity of labour, for example, may be due to better planning of the work on the part of the management or to the installation of new machinery. An increase in the productivity of materials may be due to greater skill on the part of workers, to improved designs, and so on.
Examples of each type of productivity may make its meaning clearer.

- **PRODUCTIVITY OF LAND**
  If by using better seed, better methods of cultivation and more fertiliser the yield of corn from a particular hectare of land can be increased from 2 quintals to 3 quintals, then the productivity of that land, in the agricultural sense, has been increased by 50 per cent. The productivity of land used for industrial purposes may be said to have been increased if the output of goods or services within that area of land is increased by whatever means.

- **PRODUCTIVITY OF MATERIALS**
  If a skilful tailor is able to cut 11 suits from a bale of cloth from which an unskilful tailor can only cut ten, then in the hands of the skilful tailor the bale was used with 10 per cent. greater productivity.

- **PRODUCTIVITY OF MACHINES**
  If a machine tool has been producing 100 pieces per working day and through the use of improved cutting tools its output in the same time is increased to 120 pieces, then the productivity of that machine has been increased by 20 per cent.

- **PRODUCTIVITY OF MEN**
  If a potter has been producing 30 plates an hour and improved methods of work enable him to produce 40 plates an hour, the productivity of that man has increased by 33 1/3 per cent.

In each of these deliberately simple examples output—or production—has also increased, and in each case by exactly the same percentage as the productivity. But an increase in production does not by itself indicate an increase in productivity. If the input of resources goes up in direct proportion to the increase in output the productivity will stay the same. And if input increases by a greater percentage than output, then higher production will be being achieved at the expense of a reduction in productivity.

In short, higher productivity means that more is produced with the same expenditure of resources, i.e. at the same cost in terms of land, materials, machine time or labour; or alternatively that the same amount is produced at less cost in terms of land, materials, machine time or labour used up, thus releasing some of these resources for the production of other things.

4. **RELATIONSHIP BETWEEN INCREASED PRODUCTIVITY AND HIGHER LIVING STANDARDS**

We can now see more clearly how higher productivity can contribute to a higher standard of living. If more is produced at the same cost, or the same amount
Productivity and the Standard of Living

is produced at less cost, there is a gain to the community as a whole, which may take various forms. A Meeting of Experts on Productivity in Manufacturing Industries convened by the I.L.O. in December 1952 summed up the main forms which this gain may take, in the following words:

Higher productivity provides opportunities for raising the general standard of living, including opportunities for—

(a) larger supplies both of consumer goods and of capital goods at lower costs and lower prices;
(b) higher real earnings;
(c) improvements in working and living conditions, including shorter hours of work; and
(d) in general, a strengthening of the economic foundations of human well-being.¹

5. PRODUCTIVITY IN INDUSTRY

The problems of raising the productivity of the land and of livestock are the field of the agricultural expert. This book is not concerned with them. It is mainly concerned with raising productivity in industry, especially manufacturing industry. The techniques of work study described in it can, however, be used with success wherever work is done, in factories or offices, in shops or public services, and even on farms.

Cloth for clothes, many parts of houses, sanitary ware, drainage and waterworks equipment, drugs and medical supplies, equipment for hospitals and for defence are all the products of industry. So are many things necessary for living above the level of bare existence. Household utensils, furniture, lamps and stoves generally have to be made in workshops, large and small. Many of the goods necessary for running a modern community are too complex and too heavy to be made by cottage or small-scale industry. Railway engines and carriages, motor trucks, electric generators, telephones, electric cables, all require expensive machines to make them, special equipment to handle them and an army of workers of many different skills. The greater the productivity of the establishments making these things, the greater are the opportunities of producing them abundantly and cheaply in quantities and at prices which will meet the requirements of every family in the community.

The factors affecting the productivity of each organisation are many, and no one factor is independent of others. The importance to be given to the productivity of each of the resources—land, materials, machines or men—depends on the enterprise, the industry and possibly the country. In industries where labour costs are low compared with material costs (such as the cotton industry in the United Kingdom) or

compared with the capital invested in plant and equipment (as in heavy chemical plants, power stations or paper mills) better use of materials or plant may give the greatest scope for cost reduction. In countries where capital and skill are short, while unskilled labour is plentiful and poorly paid, it is especially important that higher productivity should be looked for by increasing the output per machine or piece of plant or per skilled worker. It often pays to increase the number of unskilled workers if by doing so an expensive machine or a group of skilled craftsmen are enabled to increase output. Most practical managers know this, but many people have been misled into thinking of productivity exclusively as the productivity of labour, mainly because labour productivity usually forms the basis for published statistics on the subject. In this book the problem of raising productivity will be treated as one of making the best possible use of all the available resources, and attention will constantly be drawn to cases where the productivity of materials or plant is increased.

6. THE BACKGROUND OF PRODUCTIVITY

To achieve the greatest increases in productivity action must be taken by all sections of the community: governments, employers and workers.

Governments can create conditions favourable to the efforts of employers and workers to raise productivity. For these it is necessary, among other things—

1. to have balanced programmes of economic development;
2. to take the steps necessary to maintain employment;
3. to try to make opportunities for employment for those who are unemployed or underemployed, and for any who may become redundant as a result of productivity improvement in individual plants.

This is especially important in developing countries where unemployment is a big problem.

Employers and workers also have vital parts to play. The main responsibility for raising productivity in an individual enterprise rests with the management. Only the management can carry out a productivity programme in each company. Only the management can create good human relations and so obtain the co-operation of the workers which is essential for real success, though this requires the goodwill of the workers too. Trade unions can actively encourage their members to give such co-operation when they are satisfied that the programme is in the interests of the workers, as well as of the country as a whole.

7. THE ATTITUDE OF THE WORKERS

One of the greatest difficulties in obtaining the active co-operation of the workers is the fear that raising productivity will lead to unemployment. Workers
fear that they will work themselves out of their jobs. This fear is greatest when unemployment already exists and a worker who loses his job will find it hard to get another. Even in the economically developed countries where employment has for years been at a very high level this fear is very real to those who knew unemployment in the past.

Since this is so, workers, unless they are assured of adequate assistance in meeting their problems, may resist any steps which they fear, rightly or wrongly, will make them redundant, even though their period of unemployment may only be a short one, while they are changing jobs.

In addition to the steps which governments may take to maintain the general level of employment, something more is needed to help workers who become temporarily unemployed. With this in mind the I.L.O. Meeting of Experts on Productivity in Manufacturing Industries (Geneva, 1952) made certain recommendations. It recommended that there should be advance planning by employers of changes in industrial processes and equipment, and advance notification of displacements expected to result from these; that where changes are planned which would make certain jobs redundant, consideration should be given to reducing or suspending new recruitment with a view to retaining redundant workers until sufficient jobs become available for them as a result of normal labour turnover; that employers should give preference to displaced workers when filling vacancies in other departments, due account being taken of efficiency, good conduct and seniority; that training and retraining courses should, where appropriate, be provided to enable workers to be transferred to other work; that improvements should be made, where necessary, in the organisation of employment services; that appropriate measures should be taken to make it easier for workers to move, if necessary, to other places where jobs are available; and that measures should be taken, through unemployment insurance schemes and in other ways, to protect the living standards of workers who might lose their jobs.

An example of action on these lines is the agreement reached by representatives of employers and labour in the Indian cotton industry at a meeting called by the Indian Government at Delhi in February 1951. Essentially the same points were embodied in India's First Five-Year Plan, which was launched in 1952.

Even with written guarantees, steps taken to raise productivity will probably meet with resistance. This resistance can generally be reduced to a minimum if everybody concerned understands the nature of and reason for each step taken and has some say in its implementation. Workers' representatives should be trained in the techniques of increasing productivity so that they will be able both to explain them to their fellow-workers and to use their knowledge to ensure that no steps are taken which are directly harmful to them. Many of the safeguards mentioned above can best be implemented through joint productivity committees and works councils.
CHAPTER 2

PRODUCTIVITY
IN THE
INDIVIDUAL ENTERPRISE

It was said in Chapter 1 that there were a number of factors affecting the productivity of an enterprise. Some of these, such as the general level of demand for goods, taxation policy, interest rates and the availability of raw materials, suitable equipment or skilled labour, are outside and beyond the control of any one employer. Certain other factors can be controlled from inside the enterprise, and it is these that we are now going to discuss.

1. RESOURCES AT THE DISPOSAL OF AN ENTERPRISE

Productivity was defined as “the ratio between output and input” in an enterprise, an industry or an economy as a whole.
Productivity in the Individual Enterprise

The productivity of a certain set of resources (input) is therefore the amount of goods or services (output) which is produced from them. What are the resources at the disposal of a manufacturing company? They are—

- **LAND AND BUILDINGS**
  Land in a convenient location on which to erect the buildings and other facilities necessary for the operations of the enterprise, and the buildings erected on it.

- **MATERIALS**
  Materials that can be converted into products to be sold. They include fuel, chemicals for use in the processes of manufacture, and packing materials.

- **MACHINES**
  Plant, equipment and tools necessary to carry out operations of manufacture and the handling and transport of materials; heating, ventilating and power plant; office equipment and furniture.

- **MANPOWER**
  Men and women to perform the manufacturing operations; to plan and control; to do clerical work; to design and do research; to buy and sell.

The use which is made of all these resources combined determines the productivity of the enterprise.

These resources consist of “real” things and services. When they are used up in the process of production “real” costs are therefore incurred. Their cost may also be measured in terms of money. Since higher productivity means more output from the same resources it also means lower money costs and higher net money returns per unit of output.

2. THE TASK OF THE MANAGEMENT

Who is responsible for making sure that the best use is made of all these resources? Who is responsible for seeing that they are combined in such a way as to achieve the greatest productivity? The management of the enterprise.

In any concern larger than a one-man business (and to some extent even in a one-man business) the work of balancing the use of one resource against another and of co-ordinating the efforts of everyone in the organisation to achieve the best results is the job of the management. If the management fails to do what is neces-

---

1 This discussion of productivity applies equally to non-manufacturing fields. The proper use of manpower, equipment and other resources is just as important in running a railway, an airline or municipal services as in running a factory.
FIGURE 1. THE ROLE OF THE MANAGEMENT IN CO-ORDINATING THE RESOURCES OF AN ENTERPRISE

RESOURCES

- LAND AND BUILDINGS
- MATERIALS
- PLANT MACHINES EQUIPMENT
- THE SERVICES OF MEN

THE MANAGEMENT

- OBTAINS THE FACTS
- PLANS
- DIRECTS
- CO-ORDINATES
- CONTROLS
- MOTIVATES
  in order to produce

GOODS AND SERVICES

PRODUCTS
Productivity in the Individual Enterprise

If the enterprise is not properly managed, it will fail. In such a case the four resources become unco-ordinated like the efforts of four horses without a driver. The enterprise, like a driverless coach, moves forward jerkily, now held up for lack of material, now for lack of equipment; because machines are badly chosen and even more badly maintained, or because employees are unable or unwilling to do their best. The key position of the management may be shown by a diagram (figure 1).

This is not the place to discuss the activities (listed in the figure) by which the management achieves the transformation of the resources at its disposal into finished products. It may not be out of place, however, to say something about the term "motivate", since it may be unfamiliar to some readers.

To "motivate" means to provide a motive or reason for doing something. Used in the context of management it means, in effect, to make people want to do something. It is of little use if the management carrying out the other activities of getting facts, planning and so on if the people who are supposed to carry out the plans do not want to do so, although they may have to. Coercion is no substitute for voluntary action. It is one of the tasks of the management, and perhaps its most difficult task, to make people want to co-operate; the management can only succeed fully by enlisting the willing and active participation of workers at all levels.

3. THE PRODUCTIVITY OF MATERIALS

The relative importance of each of the resources mentioned above and shown in figure 1 varies according to the nature of the enterprise, the country in which it is operating, the availability and cost of each type of resource and the type of product and process. There are many industries in which the cost of raw material represents 60 per cent. or more of the cost of the finished product (the textile industry in India, for example), the balance of 40 per cent. being divided between labour and overhead costs. There are countries, the United Kingdom and many Asian countries among them, which have to import a very large proportion of their basic raw materials and pay for them in scarce foreign currencies. Under either of these conditions the productivity of materials becomes a key factor in economic production or operation; it is likely to be far more important than the productivity of land or labour or even plant and machinery. Although the technique of work study, with which this book is concerned, deals primarily with improving the utilisation of plant and of the services of labour, it can frequently contribute to savings in materials, either directly or indirectly, as in saving the erection of buildings through the better utilisation of existing space. In general, however, savings in materials, direct or indirect, are effected in the following ways:

1 The titles of some textbooks on industrial management will be found in the book list at the end of this volume (Appendix 8).
at the design stage or time of specification—

by ensuring that the design is such that the product can be manufactured with the least possible use of materials, especially when they are scarce or dear;

by ensuring that plant and equipment specified for purchase is the most economical possible in terms of materials consumed in its operation (e.g. fuel) for a given level of performance.

at the process or operation stage—

by ensuring that the process used is the right one;

by ensuring that it is being operated correctly;

by ensuring that operatives are properly trained and motivated so that they will not turn out faulty work which has to be rejected, leading to loss of material;

by ensuring proper handling and storage at all stages from raw materials to finished products, first eliminating all unnecessary handling and movement; and

by proper packaging to avoid damage in transit to the customer.

The question of material saving is so important to many countries that a separate volume would be needed to discuss it.

4. THE PRODUCTIVITY OF LAND, BUILDINGS, MACHINES AND MANPOWER

The effective utilisation or maximum productivity of land and buildings is an important source of cost reduction, especially when an enterprise is expanding and needs increased working space. Any reduction in the original specification which can be effected before land is purchased or buildings erected represents a saving in capital outlay (or rental) of land and buildings, a saving in materials, particularly fittings, which may have to be imported, and a probable saving in taxes as well as a saving in future maintenance costs. An example from India of a saving of 200,000 rupees due to the application of work study to achieve better use of existing space can be matched by the experience of a very large United Kingdom company in which on at least two occasions the use of work study in existing factories has enabled expansion of activities to take place in the present buildings, resulting in the cancellation of building projects of over £1 million each. Examples of space saving and the techniques of work study employed to achieve them will be found in Chapters 9 and 10.

We now come to consider the productivity of plant, machinery and equipment and of the services of men and women. Let us take another look at the nature of
Productivity in the Individual Enterprise

Productivity, which in simple terms was described as the "arithmetical ratio between the amount produced and the amount of any resources used in the course of production". To do this we have to start thinking in terms of time, since it is the output of good production from a machine or from a worker in a given time which is used in calculating productivity. Productivity is frequently measured as the output of goods or services in a given number of "man-hours" or "machine-hours".

5. HOW THE TOTAL TIME OF A JOB IS MADE UP

- A man-hour is the labour of one man for one hour.
- A machine-hour is the running of a machine or piece of plant for one hour.

The time taken by a man or a machine to carry out an operation or to produce a given quantity of product may be considered as made up in the following manner, which is illustrated in figure 2.

There is first—

the basic work content of the product or operation

Work content means, of course, the amount of work "contained in" a given product or process measured in man-hours or machine-hours. The basic work content is the time the product would take to manufacture or the operation to perform if the design or specification were perfect, the process or method of manufacture or operation perfectly carried out, and there was no loss of working time from any cause whatsoever during the period of the operation (other than legitimate rest pauses permitted to the operative). The basic work content is the irreducible minimum time theoretically required to produce one unit of output.

This is obviously a perfect condition which never occurs in practice, although it may sometimes be approached, especially in processing industries. In general, however, actual operation times are far in excess of it on account of—

excess work content

The work content is increased by the following:

A. Work Content Added by Defects in the Design or Specification of the Product.

This occurs primarily in manufacturing industries, but the equivalent in service industries such as transport might be the specification of a bus service which

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1 The words "or operation" are added throughout because this picture applies equally to non-manufacturing industries such as transport operation or retail selling.

2 This definition differs slightly from that given in the B.S. Glossary. See note at the bottom of figure 2.
Total Work Content

Total Time of Operation under Existing Conditions

Basic Work Content of product and/or operation

Work Content Added by defects in design or specification of product

Work Content Added by inefficient methods of manufacture or operation

Ineffective Time due to shortcomings of the management

Ineffective Time within the control of the worker

NOTE: In the British Standard Glossary of Terms in Work Study the terms "work content" and "ineffective time" are accorded precise technical meanings which differ slightly from those used here. The Glossary definitions are intended for use in applying work measurement techniques, and are not strictly relevant to the present discussion. In this chapter and the next, "work content" and "ineffective time" are used with their ordinary common meanings, as defined in the text.
Productivity in the Individual Enterprise

demands operation in a way that causes unnecessary additional transit time. This additional work content is the time taken over and above the time of the basic work content due to features inherent in the product which could be eliminated (see figure 3, page 19).

B. **Work Content Added by Inefficient Methods of Production or Operation.**

This is the time taken, over and above the basic work content plus A, due to inefficiencies inherent in the process or method of manufacture or operation (see figure 3).

* * *

The basic work content assumes uninterrupted working. In practice, however, uninterrupted working is exceptional, even in very well-run organisations. All interruptions which cause the worker or machine or both to cease producing or carrying out the operations on which they are supposed to be engaged, whatever may be the cause, must be regarded as ineffective time\(^1\) because no work effective towards completing the operation in hand is being done during the period of the interruption. Ineffective time reduces productivity by adding to the duration of the operation. Apart from interruptions from sources outside the control of anyone in the organisation, such as a power breakdown or a sudden rainstorm, ineffective time may be due to two sources—

C. **Ineffective Time Due to Shortcomings on the Part of the Management.**

Time during which man or machine or both are idle because the management has failed to plan, direct, co-ordinate or control efficiently (see figure 4, page 22).

D. **Ineffective Time within the Control of the Worker.**

Time during which man or machine or both are idle for reasons within the control of the worker himself (see figure 4).

The relative sizes of the different sections of figure 2 have no special significance and will vary from operation to operation and from undertaking to undertaking even for the same operation. The application of work study has often made it possible to reduce operation times to one-half or even a third of their original values without by any means exhausting the possibilities of further reduction.

Let us now examine each of these sets of causes of excess time (excess work content or ineffective time) in turn and look at some of the reasons for them in detail.

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\(^1\) See note at bottom of figure 2.
FIGURE 3. THE WORK CONTENT DUE TO THE PRODUCT AND PROCESSES

Total Work Content

A. 1. Bad Design of Product prevents use of most economic processes
A. 2. Lack of Standardisation prevents use of high-production processes
A. 3. Incorrect Quality Standards cause unnecessary work
A. 4. Design demands removal of Excess Material

B. 1. Wrong Machine used
B. 2. Process Not Operated Correctly or in bad conditions
B. 3. Wrong Tools used
B. 4. Bad Layout causing wasted movement
B. 5. Operative's Bed Working Methods

Work Content Added by defects in design or specification of the product

Work Content Added by inefficient methods of manufacture or operation

Ineffective Time (see figure 4)
Productivity in the Individual Enterprise

6. FACTORS TENDING TO REDUCE PRODUCTIVITY

A. Work Content Added Due to the Product (Figure 3).

How can features of the product affect the work content of a given operation?

There are several ways in which this can happen:

(1) The product and its components may be so designed that it is impossible to use the most economical processes or methods of manufacture. This applies especially to the metalworking industries and most particularly where large-scale production is undertaken. Components may not be designed to take advantage of high-production machinery (example: a sheet-metal part may be so designed that it has to be cut out and riveted or welded instead of being pressed in one piece).

(2) Excessive variety of products or lack of standardisation* of components may mean that batches of work have to be small and cannot be put on special-purpose high-production machines but have to be done on slower general-purpose machines (see also C 2).

(3) Incorrect quality standards, whether too high or too low, may increase work content. In engineering practice close tolerances, requiring extra machining, are often put on dimensions where they are quite unnecessary. There will thus be more rejects and a corresponding waste of material. On the other hand, material of too low a quality may make it difficult to work to the finish required or may make additional preparation of the product, such as cleaning, necessary to make it usable. The quality of material becomes especially important in connection with automation.

(4) The components of a product may be so designed that an excessive amount of material has to be removed to bring them to their final shape. This increases the work content of the job and wastes material as well (example: shafts with very large and very small diameters designed in one piece).

The first step towards raising productivity and lowering the cost of the product is therefore to eliminate as far as possible all features in its design and specification that are likely to cause excess work content, including non-standard products demanded by customers where a standard product would serve as well.

B. Work Content Added Due to the Process or Method* (Figure 3).

How can inefficient operation of the process or inefficient methods of production or operation affect the work content of the job?

* See Appendix 5, page 413, for definitions of management terms marked with an asterisk in this and subsequent chapters.
Productivity in the Individual Enterprise

(1) If the wrong type or size of machine is used, one which has a lower output than the correct one (examples: small capstan work put on a turret or centre lathe; narrow cloth put on too wide a loom).

(2) If the process is not operating properly, that is at the correct feed, speed, rate of flow, temperature, density of solution or whatever conditions govern its operation, or if the plant or machine is in bad condition.

(3) If the wrong hand tools are used.

(4) If the layout of the factory, shop or workplace causes wasted movement, time or effort.

(5) If the working methods of the operative cause wasted movement, time or effort.

It should be noted that the idea of work content in terms of time is based on the assumption of operation at a steady average working pace. The additional time taken owing to a slowing up of the working pace might be considered as ineffective time, but this is unimportant for the present discussion.

Optimum productivity from the process will only be reached if it is operated with the least waste of movement, time and effort and under the most efficient conditions. All features which would cause the worker to make unnecessary movements, whether around the shop or at the workplace, should be eliminated.

It will be seen that all the items in the excess work content may be attributed to deficiencies on the part of the management. This is true even of bad working methods on the part of the operatives if these are due to failure of the management to see that operatives are properly trained and supervised.

C. Ineffective Time Due to the Management (Figure 4).

Let us now consider the ineffective time in the manufacturing or operating cycle. How can shortcomings on the part of the management affect it?

(1) By a marketing policy* which demands an unnecessarily large number of types of product. This causes short runs of each type, and machines are idle while they are being changed over to manufacture different products. The workers do not have the opportunity to acquire skill and speed in any one operation.

(2) By failing to standardise component parts as far as possible between products or within product. This has the same effect—that is, short runs and idle time.¹

¹ LIKE “work content and ineffective time”, the term “idle time” is given a special meaning in the B.S. Glossary. The Glossary meaning is not relevant here.
FIGURE 4. INEFFECTIVE TIME DUE TO SHORTCOMINGS ON THE PART OF MANAGEMENT AND WORKERS

NOTE: "Idle Time" is used here in the ordinary sense of the term, not that defined in the B.S. Glossary.
(3) By failing to ensure that designs are properly developed or that customers’ requirements are met from the beginning. This results in changes of design causing stoppages of work and loss of machine- and man-hours as well as waste of material.

(4) By failing to plan the flow of work and of orders, with the result that one order does not follow immediately on another and plant and labour are not continuously employed.

(5) By failing to ensure a supply of raw materials, tools and other equipment necessary to do the work, so that plant and labour are kept waiting.

(6) By failing to maintain plant and machines properly. This leads to stoppages due to machine breakdowns.

(7) By allowing plant and machinery to be operated in bad condition so that work is scrapped or returned for rectification and has to be done again. Time spent in rework is ineffective.

(8) By failing to provide working conditions in which the operative can work steadily.

(9) By failing to take proper precautions for the safety of workers. This causes lost time due to accidents.

D. Ineffective Time within the Control of the Worker (Figure 4).

Finally, how can action (or inaction) on the part of the workers themselves cause ineffective time?

(1) By workers taking time off work without good cause: by lateness, by failing to start work immediately after clocking in, by idling at work or by deliberately working slowly.

(2) By careless workmanship causing scrap or making it necessary for work to be done again. Work which has to be done again means wasted time, and scrap means wasted materials.

(3) By failing to observe safety regulations and by having or causing accidents through carelessness.

In general far more ineffective time is due to management shortcomings than to causes within the control of workers. In many industries the individual worker has very little control over the conditions under which he is required to operate. This is especially true of industries using a lot of plant and machinery and making a complex product (see next chapter).

If all the factors enumerated under the four heads above can be eliminated (the ideal case which, of course, never occurs in real life), the minimum time for the production of a given output and hence the maximum productivity is achieved.
CHAPTER 3

MANAGEMENT TECHNIQUES TO REDUCE WORK CONTENT AND INEFFECTIVE TIME

How can maximum productivity with existing resources be approached? In every case it must be as a result of action by the management, with the co-operation of workers, together with, in some cases, extra technical or scientific knowledge.

1. THE NATURE OF MANAGEMENT

What is management?

Management is the organisation and control of human activity directed towards specific ends.2

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1 In the B.S. Glossary the terms “work content”, “ineffective time” and “idle time” are all accorded precise meanings which differ slightly from those adopted in this chapter and the previous one. The differences are of no significance in the context of the present discussion.

2 There are many definitions of management; this rather general one seems the most suitable for our purpose. It should be noted that the word “management” is used by itself as an abstract noun only. Whenever the people who do the managing are intended they are referred to as “the management” to avoid confusion.
The word “organisation”, here used in a broad sense, includes the activities of planning on the basis of facts obtained, direction and co-ordination.

Management is both a science and an art. There are a number of techniques or tools of management (some of them will be touched upon in this chapter) which, systematically and correctly applied, will produce results that can be forecast reasonably accurately. The key word is “systematically”. The systematic approach to the solution of problems, proceeding step by step from the known to the unknown, always on a basis of ascertained fact (as far as is humanly possible) is the prime characteristic which differentiates science from magic, alchemy and all the other attempts to penetrate the secrets of the universe which preceded it. The systematic approach is at the root of all sound modern management theory.

Management techniques are systematic procedures of investigation, planning or control which can be applied to management problems.

These techniques can be learned in the classroom or from a textbook, but practical experience is always necessary before they can be safely applied in a factory. They are not as hard and fast as many techniques in science or technology and usually have to be adapted to the requirements of the existing situation.

Because management deals with human beings, it can never be completely scientific, and must be regarded partly as an art. The reason for this is that while scientific techniques are applied to materials governed by known physical laws, the techniques of management are applied to people and must rely on people to ensure that they are properly applied. They can only be successfully applied by someone who has learned to understand people by experience of dealing with them. This aspect of management in its relation to work study will be dealt with later, so it is unnecessary to say more about it here.

What are the management techniques which may be applied to reduce the waste of time and effort which occurs due to the factors listed in Chapter 2, Sections 5 and 6? We shall discuss these very briefly in the following paragraphs so that the reader may see where work study fits in among other management techniques.1

2. MANAGEMENT TECHNIQUES TO REDUCE THE WORK CONTENT DUE TO THE PRODUCT

If the design of the product is such that it is not possible to use the most economical processes and methods of manufacture, this usually happens because designers are not familiar enough with workshop processes; it is especially liable to occur

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1 In order not to break up the text, definitions of all the techniques mentioned are given in Appendix 5.
Management Techniques

in the metalworking industries. The weakness can be overcome by the close working together of design and production staffs from the beginning. If the product is to be produced in large quantities or is one of a range of similar products produced by the firm, improvement to make it easier to produce can be undertaken at the product development* stage, when production staff can examine the components and assemblies and call for changes before money has been spent on production, tools and equipment. At this time also, alterations in design can be made to avoid having to remove too much material, and tests can be made in running the product to ensure that it meets the technical specifications demanded. The equivalent to the product development stage in the chemical and allied industries is the pilot plant*. In transport, a non-manufacturing industry, the equivalent is the experimental service or the proving flights which are carried out on airliners.

Specialisation* and standardisation, which are discussed more fully in Section 4, are the techniques by which the variety of products or components can be reduced and batch sizes increased so that use can be made of high-production processes.

If quality standards are higher than necessary for the efficient functioning of the product the time taken to manufacture it will generally be greater because of the extra care required; unnecessary rejects will also be caused. Customers sometimes make demands for dimensional tolerances or finishes of higher standards than necessary. On the other hand, neglecting quality, especially the quality of materials purchased, may prolong the time of manufacture because the materials may be difficult to work. A case of this kind was brought to light by a trainee of the Indian Productivity Centre while carrying out a work study investigation. He found that operatives had great difficulty in assembling black bolts and nuts because of variations in the dimensions of both, although they were supposed to be standard products and interchangeable. Inquiry showed that the buying office of the firm had purchased them from suppliers other than the usual ones because they were a little cheaper. If the quality of the product as a whole is too low, sales will be lost. Quality standards must be right. The management must be sure of the requirements of the market and of the customer, and of the technical requirements of the product itself. The first two may be established by market research* and consumer research*. Where the quality level is set by technical considerations product research* may be necessary to establish what it should be. Ensuring that quality requirements are met in the production shops is the concern of the quality control* or inspection* function. The men who perform this function must be properly informed of the quality level required and should be able to advise the designers which quality standards can safely be altered to achieve higher productivity.

Figure 5 shows the effect of applying these techniques to reduce the work content of the product.1 Yet another, which is used also to reduce the work content

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1 In the figures in this chapter, as in the last, no special significance attaches to the sizes of the various rectangles; the figures are for illustration only.
FIGURE 5. HOW MANAGEMENT TECHNIQUES CAN REDUCE EXCESS WORK CONTENT

A.1. Product Development and Value Analysis reduce excess work content due to design defects
A.2. Specialisation and Standardisation enable high-production processes to be used
A.3. Market, Consumer and Product Research ensure correct quality standards
A.4. Product Development and Value Analysis reduce work content due to excess material
B.1. Process Planning ensures selection of correct machines
B.2. Process Planning and Research ensure correct operation of processes
B.3. Process Planning and Method Study ensure correct selection of tools
B.4. Method Study reduces work content due to bad layout
B.5. Method Study and Operator Training reduce work content due to bad working methods
due to the process or method, is value analysis, the systematised investigation of the product and its manufacture to reduce cost and improve value.

3. MANAGEMENT TECHNIQUES TO REDUCE THE WORK CONTENT DUE TO THE PROCESS OR METHOD

If the proper steps are taken to remove features making unnecessary work in the product before production actually starts effort can be concentrated on reducing the work content of the process.

In industries which have developed their practice from engineering it is usual, today, for the process planning* function to be responsible for specifying the machines on which the product and its components shall be made, the types of tools necessary and the speeds, feeds and other conditions under which the machines shall be run. In the chemical industries these conditions are usually laid down by the scientists in the research department. In all types of manufacturing industry it may be necessary to do process research* in order to discover the best manufacturing techniques. Proper maintenance* will ensure that plant and machinery is operating properly and will prolong its life, so reducing capital expenditure. Process planning combined with method study* will ensure the selection of the most suitable tools for the operative.

The layout of the factory, shop or workplace and the working methods of the operative are the task of method study, one of the two branches of work study* which forms the main subject of this book. As method study will be discussed in detail in Chapters 7 to 12 nothing more will be said about it here. Coupled with method study is operator training* as an aid to improving the working methods of the operative.

Figure 5 shows the effect of these techniques when applied to reducing the work content of the process.

4. MANAGEMENT TECHNIQUES TO REDUCE INEFFECTIVE TIME DUE TO THE MANAGEMENT

The responsibility of the management for the achievement of high productivity is always great, especially in the reduction of ineffective time. Ineffective time can be a source of great loss even where working methods are very good.

The reduction of ineffective time starts with the policy of the directors concerning the markets which the firm shall try to serve (marketing policy). Shall the firm specialise in a small number of products made in large quantities at the lowest possible price and sell them cheaply, or shall it try to meet the special requirements of every customer? The level of productivity achievable will depend on the answer to this question. To make many different types of product means that machines
Total Time if All Techniques Perfectly Applied

Basic Work Content

Basic Work Content

Ineffective Time Totally Eliminated if All Techniques Perfectly Applied

C.1. Marketing and Specialisation reduce idle time due to product variety

C.2. Standardisation reduces idle time due to short runs

C.3. Product Development reduces ineffective time due to changes in design

C.4. Production Control based on Work Measurement reduces idle time due to bad planning

C.5. Material Control reduces idle time due to lack of raw materials

C.6. Maintenance reduces idle time of men and machines due to breakdowns

C.7. Maintenance reduces ineffective time due to plant in bad condition

C.8. Improved Working Conditions enable workers to work steadily

C.9. Safety measures reduce ineffective time due to accidents

D.1. Sound Personnel Policy and Incentives reduce ineffective time due to absence, etc.

D.2. Personnel Policy and Operator Training reduce ineffective time due to carelessness

D.3. Safety Training reduces ineffective time due to accidents

FIGURE 6. HOW MANAGEMENT TECHNIQUES CAN REDUCE INEFFECTIVE TIME
Management Techniques

have to be stopped in order to change from one type to another; workers are unable to gain speed on work because they never have enough practice on any one job.

This decision must be taken with a full understanding of its effects. Unfortunately, in many companies, variety of product grows unnoticed through attempts to make sales by meeting every special demand for variations, most of which are generally unnecessary. Specialisation is, therefore, an important step towards eliminating ineffective time.

Standardisation of components will also reduce ineffective time. It is often possible to standardise most of the components in a range of models of the same type of product; this gives longer runs and reduces the time spent in changing over machines.

Much ineffective time is caused by failing to ensure that the product is functioning correctly or meets the requirements of the customers before it is put into full production. This results in parts having to be redesigned or modified, and these modifications mean wasted time, material and money. Every time a batch of parts has to be remade there is ineffective time. The function of product development mentioned in Section 2 above is to make these modifications before work begins in the production shops.

The planning of proper programmes of work so that plant and workers are kept supplied with jobs without having to wait is known as production planning* and the control of that programme to ensure its being carried out is production control*. A proper programme can only be worked out and applied on the basis of sound standards of performance. These are set by the use of work measurement*, the second technique of work study: The importance of knowing accurately how long each job may be expected to take is discussed at length in the chapters on work measurement.

Workers and machines may be made idle because materials or tools are not ready for them when they are needed. Material control* ensures that these requirements are foreseen and fulfilled in time, and at the same time that materials are bought as economically as possible and that the stocks maintained are not excessive. In this way the cost of holding stocks of materials is kept down.

Machines and plant which break down cause idleness, reduce productivity and increase manufacturing costs. Breakdowns can be reduced by proper maintenance. Plant and machinery in bad condition will turn out bad work, some of which may have to be scrapped. This takes time which must be regarded as ineffective.

If management fails to provide good working conditions ineffective time will be increased because workers will have to take more rest to overcome fatigue or the effects of heat, fumes, cold or bad lighting. If management fails to take the
Management Techniques

proper precautions for the safety of the workers ineffective time will be increased owing to loss of time through accidents.

It will be seen that even where the work content of the product and process has been reduced as much as possible under the existing conditions, it is still possible for there to be a great deal of waste simply through failure to use time properly. Much of the responsibility for this rests with the management.

Figure 6 shows how this excess time can be reduced by applying the management techniques mentioned.

5. MANAGEMENT TECHNIQUES TO REDUCE INEFFECTIVE TIME WITHIN THE CONTROL OF THE WORKER

Whether the available time is fully used also depends on the workers. It is widely believed that someone doing a manual job can work faster or slower according to his choice. This is true only up to a certain point. Most people who have been doing a job for a long time have a certain pace at which they work best and at which they will normally work. Usually a worker trained at and accustomed to his job cannot actually work much faster, except for short periods, and equally feels uncomfortable if forced to work more slowly than his natural pace. Any attempt to speed up the rate of working, except by proper training, will tend to increase the number of errors made. The worker can save time mainly by reducing the amount of time when he is not working, that is, when he is resting, talking to his fellow workers, having a smoke, waiting to clock off, late or absent.

In order to reduce this ineffective time he must be made to want to reduce it, and it is the business of management to create the conditions which will make him want to get on with his work.

First, bad working conditions make it difficult to work for long stretches at a time without frequent periods of rest and produce an attitude of mind in the worker which makes him feel that he does not want to try.

Second, if the worker feels that he is simply looked upon by management as a tool of production without regard for his feelings as a human being he will not want to make a greater effort than he has to in order to keep his job.

Third, if the worker does not know what he is doing or why he is doing it, if he knows nothing of the work of the firm as a whole, he can hardly be expected to give of his best.

Fourth, if the worker feels that he does not receive justice from management the feeling of grievance will hinder him from doing his best.
The willingness of the worker to get on with the job and reduce this ineffective time depends very much on the personnel policy* of the management and its attitude to him. Personnel policy involves the whole relationship between the management and employees; if this relationship is not a good one it is very difficult to make any management techniques work satisfactorily. To create the right conditions for good relationships is part of the art of management. A sound personnel policy includes the training of managers and supervisors of all ranks in proper attitudes to and relations with the workers.

A soundly based wage structure, including, where appropriate, incentive schemes* based on accurate time standards—usually set by work measurement—which allows the worker to earn in some measure in proportion to his output, will discourage any tendency to waste time and hence will make for high productivity.

Careless workmanship and the carelessness which leads to accidents are both the results of bad attitudes of mind on the part of workers which can only be overcome by a suitable personnel policy and proper training. It will be seen, therefore, that management has a very great responsibility for reducing the ineffective time due to the action or inaction of workers.

This reduction is shown diagrammatically in figure 6.

6. MANAGEMENT TECHNIQUES AFFECT ONE ANOTHER

None of the techniques of management which have been discussed can properly be applied in isolation. Each one has effects on others. It is impossible to plan programmes of work properly or to set up good incentive schemes without the standards provided by work measurement. Method study can be used to simplify the design of the product so that it is both easier to use and easier to produce. Production planning will be made easier if a sound personnel policy and a well-applied incentive scheme encourage workers to perform reliably. Standardisation will make the job of material control easier by demanding less variety of materials to be bought and held in stock. Process research, by eliminating features of the plant likely to break down, should make easier the application of a proper system of maintenance.

* * *

It will be seen that in our discussion in this chapter we have gradually moved from a study of the question of productivity in the enterprise as a whole to the productivity of a certain part of it, namely, the productivity of the plant and labour—machines and men. We have looked briefly at some of the management techniques which can affect that productivity so as to show the many different ways in which problems of productivity can be attacked. For the rest of the book we are going to concentrate on one of those techniques, namely work study.
WORK STUDY

1. WHAT IS WORK STUDY?

What is work study, and why should it be selected from among the many management techniques discussed in the last chapter as the main weapon of attack on the problem of increasing productivity, and as a special subject for this book?

Work study is a generic term for those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement.¹

¹ The definition given here is that adopted in the British Standard Glossary of Terms in Work Study.
Work study is thus especially concerned with productivity. It is most frequently used to increase the amount produced from a given quantity of resources without further capital investment except, perhaps, on a very small scale.

Work study was widely known for years as "time and motion study", but with the development of the technique and its application to a very wide range of activities it was felt by many people that the older title was both too narrow and insufficiently descriptive. The term "work study" entered the English language only after the Second World War, but it is now generally accepted; "motion and time study" is however still used in the United States although the newer term is gaining currency there. The word Arbeitsstudium, which has a similar meaning, has been used in Germany for many years.

2. WORK STUDY: A DIRECT MEANS OF RAISING PRODUCTIVITY

We have already seen that the factors affecting the productivity of any enterprise are many, that they will vary in importance according to the nature of the activities undertaken, and that they are dependent on one another.

Let us now look at this problem from a different angle. So far, in discussing the use of management techniques to increase productivity, there has been no mention of major capital expenditure in plant or equipment. It has been assumed that productivity would be raised by using existing resources. Productivity can almost always be greatly increased by heavy investment of money in new and improved plant and equipment. How much can we expect to gain through the use of management techniques, and especially work study, to improve the use of existing resources as against investing capital in new plant? Any comparison made in general terms will only be a rough guide. It is convenient to do this in the form of a table (table 1).

It will be seen that the most effective way of raising productivity in the long run is often the development of new processes and the installation of more modern plant and equipment. This, however, is only true of those industries where production is dependent mainly on machines and plant rather than on human labour. Continuous chemical processes and also many textile processes are of this kind. The research and development necessary to develop a new process or a machine of higher performance are usually expensive and take a long time, and there is always the risk that the improvements achieved may not justify the time and money spent. Even to achieve worthwhile improvements in existing processes may take considerable time and money. In countries where there is little capital to spare and where the need for increased productivity is urgent this approach to the problem may not even be possible.

It will have been noticed that the human element has been emphasised. This is because work study is concerned primarily with operation rather than with technical processes as such, and operation involves human beings, whether as workers,
planners, technicians or managers. The study of the behaviour of plant divorced from the operator is almost entirely a technical problem, and work study is not usually concerned with it.

Work study, being a management technique, shares the characteristic of all management techniques mentioned in the last chapter, namely that of being a **systematic procedure**. That is its strength as a "tool" of investigation and improvement.

### 3. WHY IS WORK STUDY VALUABLE?

There is nothing new about the investigation and improvement of operations in the workshop or elsewhere; good managers have been investigating and improving ever since human effort was first organised on a large scale, which must have been long before the Pyramids were built in Egypt. Managers of outstanding ability—geniuses—have always been able to make notable advances. Unfortunately there are as few geniuses in industry as elsewhere. There are not nearly enough to go round. The prime value of work study lies in the fact that by carrying out its systematic procedures quite ordinary men can achieve results as good as or better than the less systematic genius was able to achieve in the past.

Work study succeeds because it is systematic both in investigation of the problem being considered and in the development of its solution. Systematic investigation takes time. It is therefore necessary, in all but the smallest firms, to separate the job of making work studies from the task of management. The factory manager or shop foreman, in his day-to-day work, with its many human and material problems, is never free from interruption for long. However capable he may be, a manager can rarely afford to devote a long time, without interruption, to the study of a single activity on the factory floor. This means that it is almost always impossible for him to obtain all the facts on what is happening in the course of that activity. Unless all the facts are known it is impossible to be sure that any alterations in procedure which are made are based on accurate information and will be fully effective. It is no use relying on the word of operators or foremen, because it has been proved again and again that they do not always know what is really happening. Only by continuous study at the workplace or in the area where the activity is taking place can the facts be obtained. This means that work study must always be the responsibility of someone who is able to undertake it full time, without direct management duties: someone in a staff and not a line position.¹

Work study is a service to management and supervision.

We have now discussed, very briefly, some aspects of the nature of work study and why it is such a valuable "tool" of management. There are other reasons to be added to the above, which are summarised at the top of page 40.

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¹ A person in a "line" position exercises direct supervisory and disciplinary authority over the ranks below him. A "staff" appointee, on the other hand, is strictly an adviser with no power or authority to put his recommendations into operation. His function is to provide expert information.
TABLE 1. DIRECT MEANS

<table>
<thead>
<tr>
<th>Approach</th>
<th>Type of improvement</th>
<th>Means</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital investment</td>
<td>1. Development of new basic process or fundamental improvement of existing ones</td>
<td>Basic research</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>2. Install more modern or higher-capacity plant or equipment or modernise existing plant</td>
<td>Applied research, Pilot plant</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>3. Reduce the work content of the product</td>
<td>Purchase</td>
<td></td>
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<td></td>
<td>4. Reduce the work content of the process</td>
<td>Process research, Pilot plant</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>5. Reduce ineffective time (whether due to management or to workers)</td>
<td>Work measurement</td>
<td>Low</td>
</tr>
<tr>
<td>Better management</td>
<td></td>
<td>Method study, Value analysis</td>
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<td></td>
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<td>Product development, Quality management</td>
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<td></td>
<td>Process planning, Method study</td>
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<td>Operator training, Value analysis</td>
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<td></td>
<td></td>
<td>Marketing policy, Standardisation, Product development, Production planning and control, Material control, Planned maintenance, Personnel policy, Improved working conditions, Operator training, Incentive schemes</td>
<td></td>
</tr>
</tbody>
</table>
## OF RAISING PRODUCTIVITY

<table>
<thead>
<tr>
<th>How quickly can results be achieved</th>
<th>Extent of improvement in productivity</th>
<th>The role of work study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generally years</td>
<td>No obvious limit</td>
<td><strong>Method study</strong> to improve ease of operation and maintenance at design stage</td>
</tr>
<tr>
<td>Immediately after installation</td>
<td>No obvious limit</td>
<td><strong>Method study</strong> in plant layout and to improve ease of operation when modernising</td>
</tr>
<tr>
<td>Generally months</td>
<td>Limited—of the same order as that to be expected from 4 and 5. Should <em>precede</em> action under those heads</td>
<td><strong>Method study</strong> (and its extension, value analysis) to improve design for ease of production</td>
</tr>
<tr>
<td>Immediate</td>
<td>Limited, but often of a high order</td>
<td><strong>Method study</strong> to reduce wasted effort and time in operating the process by eliminating unnecessary movement</td>
</tr>
<tr>
<td>May start slowly but effect grows quickly</td>
<td>Limited, but often of a high order</td>
<td><strong>Work measurement</strong> to investigate existing practice, locate ineffective time and set standards of performance as a basis for— A. Planning and control B. Utilisation of plant C. Labour cost control D. Incentive schemes</td>
</tr>
</tbody>
</table>
Work Study

(1) It is a means of raising the productive efficiency (productivity) of a factory or operating unit by the reorganisation of work, a method which normally involves little or no capital expenditure on plant and equipment.

(2) It is systematic. This ensures that no factor affecting the efficiency of an operation is overlooked, whether in analysing the original practices or in developing the new, and that all the facts about that operation are available.

(3) It is the most accurate means yet evolved of setting standards of performance, on which the effective planning and control of production depends.

(4) The savings resulting from properly applied work study start at once and continue as long as the operation continues in the improved form.

(5) It is a “tool” which can be applied everywhere. It can be used with success wherever manual work is done or plant is operated, not only in manufacturing shops, but in offices, stores, laboratories and service industries such as wholesale and retail distribution and restaurants, and on farms.

(6) It is one of the most penetrating tools of investigation available to management. This makes it an excellent weapon for starting an attack on inefficiency in any organisation, since, in investigating one set of problems, the weaknesses of all the other functions affecting them will gradually be laid bare.

This last point is worth further discussion. Because work study is systematic, and because it involves investigation by direct observation of all the factors affecting the efficiency of a given operation, it will show up any shortcomings in all activities affecting that operation. For example, observation may show that the time of an operator on a production job is being wasted through his having to wait for supplies of material or to remain idle through the breakdown of his machine. This points at once to a failure of material control or a failure on the part of the works engineer to carry out proper maintenance procedures. Equally, time may be wasted through short batches of work, necessitating the constant resetting of machines, on a scale which may only become apparent after prolonged study. This points to bad production planning or a marketing policy which requires looking into.

Work study acts like a surgeon’s knife, laying bare the activities of a company and their functioning, good or bad, for all to see. There is nothing like it for “showing up” people, and for this reason it must be handled, like the surgeon’s knife, with skill and care. Nobody likes being shown up, and unless the work study specialist displays great tact in his handling of people he may arouse the animosity of management and workers alike, which will make it impossible for him to do his job properly.

Managers and foremen have generally failed to achieve the saving and improvements which can be effected by work study because they have been unable to
apply themselves continuously to such things, even when they have been trained. It is not enough for work study to be systematic. To achieve really important results it must be applied continuously, and throughout the organisation. It is no use the work study man doing a good job and then sitting back and congratulating himself, or being transferred by the management to something else. The savings achieved on individual jobs, although sometimes large in themselves, are generally small when compared with the activity of the company as a whole. The full effect is felt in an organisation only when work study is applied everywhere, and when everyone becomes imbued with the attitude of mind which is the basis of successful work study: intolerance of waste in any form, whether of material, time, effort or human ability; and the refusal to accept without question that things must be done in a certain way "because that is the way they have always been done".

4. THE TECHNIQUES OF WORK STUDY AND THEIR RELATIONSHIP

Earlier in this chapter it was indicated that the term "work study" embraced several techniques, but in particular method study and work measurement. What are these two techniques and what is their relationship to one another?

Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.¹

Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.¹

Method study and work measurement are, therefore, closely linked. Method study is concerned with the reduction of the work content of a job or operation, while work measurement is mostly concerned with the investigation and reduction of any ineffective time associated with it; and with the subsequent establishment of time standards for the operation when carried out in the improved fashion, as determined by method study. The relationship of method study to work measurement is shown simply in figure 7.

As will be seen from later chapters of this book, both method study and work measurement are themselves made up of a number of different techniques. Although method study should precede the use of work measurement when time standards for output are being set, it is often necessary to use one of the techniques of work measurement, such as activity sampling (see Chapter 21) in order to determine why

¹ These definitions are those adopted in the B.S. Glossary of Terms in Work Study.
ineffective time is occurring and what is its extent, so that management action can be taken to reduce it before method study is begun. Equally, time study (Chapter 14ff.) may be used to compare the effectiveness of alternative methods.

These techniques will be dealt with in detail in the chapters devoted to them. For the present we must consider the basic procedure of work study which applies
to every study, whatever the operation or process being examined, in whatever industry. This procedure is fundamental to the whole of work study. There is no short cut.

5. THE BASIC PROCEDURE OF WORK STUDY

There are eight steps in performing a complete work study. They are—

1. Select the job or process to be studied.
2. Record from direct observation everything that happens, using the most suitable of the recording techniques (to be explained later), so that the data will be in the most convenient form to be analysed.
3. Examine the recorded facts critically and challenge everything that is done, considering in turn: the purpose of the activity; the place where it is performed; the sequence in which it is done; the person who is doing it; the means by which it is done.
4. Develop the most economic method taking into account all the circumstances.
5. Measure the quantity of work involved in the method selected and calculate a standard time for doing it.
6. Define the new method and the related time so that it can always be identified.
7. Install the new method as agreed standard practice with the time allowed.
8. Maintain the new standard practice by proper control procedures.

Steps 1, 2 and 3 occur in every study, whether the technique being used is method study or work measurement. Step 4 is part of method study practice, while step 5 calls for the use of work measurement.

The sequence—Select, Record, Examine
Develop, Measure, Define,
Install and Maintain
should be learnt by heart.

These eight steps will all be discussed in detail in the chapters devoted to method study and work measurement. Before doing so, however, we shall discuss the background and conditions necessary for work study to operate effectively.
CHAPTER 5

THE HUMAN FACTOR IN THE APPLICATION OF WORK STUDY

1. GOOD RELATIONS MUST BE ESTABLISHED BEFORE WORK STUDY IS APPLIED

Because those in authority in industrial undertakings are mainly concerned with technical and commercial matters and in meeting the challenge of their competitors, they sometimes forget that the people who work with them, particularly those under them, are as much human beings as they are, subject to all the same feelings, although they may not be able to display them openly. The man at the bottom of the ladder, the most humble labourer, resents an injustice, real or imaginary, as much as any other man. He fears the unknown, and if the unknown appears to him to offer a threat to his security of employment or to his self-respect then he will resist it, if not openly then by concealed non-co-operation or by co-operation that is only half-hearted.

Work study is not a substitute for good management and never can be. It is one of the "tools" in the manager’s tool kit, which he can use as a carpenter uses
one of his tools to produce certain results on a piece of wood. By itself it will not make bad industrial relations good, although, wisely applied, it may often improve them. This has been the experience of the I.L.O. productivity and management development missions everywhere. If work study is to contribute seriously to the improvement of productivity, relations between the management and the workers must be reasonably good before any attempt is made to introduce it, and the workers must have confidence in the sincerity of the management towards them, otherwise they will regard it as another trick to try to get more work out of them without any benefits for themselves. Of course, in certain conditions, especially where there is widespread unemployment in a country or an industry, it may be possible to impose work study, but things which are imposed are accepted reluctantly. If the conditions should change, the application will probably break down.

2. WORK STUDY AND THE MANAGEMENT

It was said in Chapter 4 that one of the principal reasons for choosing work study as the subject for this book is that it is a most penetrating tool of investigation. Because a well-conducted work study analysis is ruthlessly systematic, the places where effort and time are being wasted are laid bare one by one. In order to eliminate this waste the causes of it must be looked for. The latter are usually found to be bad planning, bad organisation, insufficient control or lack of proper training of workers. Since members of the management and supervisory staffs are employed to do these things, it will look as if they have failed in their duties. Not only this, but the increases in productivity which the proper use of work study usually brings about may appear to emphasise this failure further. Applying work study in one shop can start a chain-reaction of investigation and improvement which will spread in all directions throughout the organisation: to the plant engineer’s department, the accounts department, the design office or the sales force. The skilled worker may be made to feel a novice when he finds that his methods, long practised, are wasteful of time and effort, and that new workers trained in the new methods soon surpass him in output and quality.

Any technique which has such far-reaching effects must obviously be handled with great care and tact. Nobody likes to be made to feel that he has failed, especially in the eyes of his superiors. He loses his self-confidence and begins to ask himself whether he may not be replaced. His feeling of security is threatened.

At first sight this result of a work study investigation may seem unfair. Managers, foremen and workers, generally speaking, are honest, hard-working people who do their jobs as well as they can. They are certainly not less clever than work study specialists. Often they have years of experience and great practical knowledge. If they have failed to obtain the most from the resources at their disposal it is generally because they have not been trained in, and often do not know the value of, the systematic approach which work study brings to problems of organisation and performance of work.
This must be made clear to everybody from the very beginning. If it is not made clear, and if the work study man is at all tactless in his handling of people, then he will find that they will combine to obstruct him, possibly to the point where his task is made impossible.

If the application of work study in an enterprise is to succeed it must have the understanding and the backing of the management at all levels, starting at the top. If the top management, the managing director, the managing agent or the president of the company does not understand what the work study man is trying to do and is not giving him his full support then it cannot be expected that managers lower down will accept and support him. If the work study man then comes into conflict with them, as he may do in such circumstances, he may well find that he will lose his case, however good it may be, if an appeal is made to the top. Do not forget that in any organisation people lower down tend to take their attitudes from the man at the top.

The first group of people to whom the purpose and techniques of work study must be explained is therefore the management group, the managing director or managing agent and, in large companies or organisations, the department heads and assistant heads. It is the usual practice in most countries to run short “appreciation” courses for top management before starting to apply work study. In Imperial Chemical Industries, Ltd., which has one of the most extensive work study programmes in the United Kingdom, the chairman and members of the main board of directors have taken one- and two-day courses, while works managers, works engineers and other senior managers took an intensive two-week course at the head office. In this way over 1,000 members of management learned about work study in seven years. Most work study schools and technical colleges and national work study organisations run short courses for the managers of companies who are sending staff to be trained as specialists.

In many of the countries to which this book will find its way, such courses will be run by the productivity and management development centres. Where these are not available the work study specialist himself may have to persuade his managing director to let him organise one.

Here it is necessary to give a word of warning. Running even the simplest and shortest course in work study is not easy, and newly trained work study men are strongly advised not to try to do so by themselves. They should apply for advice and assistance to their national productivity centres. It is important that the firm’s work study staff should take an active part in the course, but they must know their subject and be able to teach it. It is far worse for the work study man to make himself look silly through bad lecturing and failing to answer questions satisfactorily than for him to do nothing.

1 A sample two-day course for directors and top managers is given in Appendix 2.
If a course for management is to be run, however, the work study man must try as hard as he can to persuade the man at the top to attend and, if possible, to open the proceedings. Not only will this show everyone that he has the support of top management, but departmental and other managers will make efforts to attend if they think their "boss" is going to be there. Here again the national productivity centres may be able to help.

3. WORK STUDY AND THE SUPERVISOR

The work study man's most difficult problem may often be the attitude of the foremen. They must be won over if he is to obtain good results from his work; indeed, their hostility may prevent him from doing any effective work at all. The foremen and their assistants represent management to the worker on the floor of the shop, and just as departmental managers will take their attitudes from the top manager, so the workers will take theirs from their supervisors. If it is evident that the foreman thinks that "this work study stuff is nonsense", then the workers will not respect the specialist and will make no efforts to carry out his suggestions, which, in any case, have to come to them through their foreman.

Before the work study man starts work in the shop, the whole purpose of work study and the procedures involved must have been very carefully explained to the foreman, so that he understands exactly what is being done and why. Unless this is done the foreman is likely to be difficult, if not actually obstructive, for many reasons; among them the following:

1. He is the person most deeply affected by work study. The work for which he may have been responsible for years is being challenged; if the work study application is successful in improving greatly the performance of the shop, he may feel that his prestige in the eyes of his superiors and of the workers will be lessened.

2. In most firms where specialists have not been used, the whole running of the shop—planning of the programmes of work, development of job methods, making up of time sheets, setting of piece rates, hiring and firing of labour—may have been done by the shop foreman. The mere fact that some of his responsibilities have been taken away from him is likely to make him feel that his status has been reduced. No one likes to think he has "lost face".

3. If disputes arise or the workers are upset he is the first person who will be called upon to clear matters up, and it is difficult for him to do so fairly if he does not understand the problem.

The sources from which foremen and supervisors are recruited differ widely in different parts of the world. In Western Europe, with its tradition of skilled
workmanship, the foreman is often selected on a basis of seniority from among the best craftsmen in the shop. This means that many foremen are middle-aged before they reach their positions and may be set in their ways. Because they have practised their trades or crafts for many years they find it difficult to believe that they have anything to learn from someone who has not spent a very long time in the same trade.

In the United States, on the other hand, it is not uncommon to appoint young college-trained men as foremen after they have spent some time working in the shops and to regard foremanship as the first step on the ladder to higher management positions.

In countries where a high percentage of workmen are illiterate it is considered essential that the foreman should be well educated. For this reason foremen in many Asian countries tend to be young and often graduates, sometimes junior members of the family owning the company.

Whatever his origin and background the foreman may well resent the introduction of a work study man into his department unless he has had some training to prepare him for it. Since foremen are nearer to the practical side of the job than the management, and so more intimately connected with work study, the work study course that they should take should be longer and more detailed than that given to the management. Foremen should know enough to be able to help in the selection of jobs to be studied and to understand the factors involved should disputes arise over methods or time standards. This means that they should be acquainted with the principal techniques of method study and work measurement and the particular problems and situations in which they should be applied. Generally speaking, courses for foremen should be full-time and of not less than one week's duration. The trainees should be given opportunities of making one or two simple method studies and of using stopwatches. The value to the work study man of a foreman who understands and is enthusiastic about what he is trying to do cannot be overemphasised. He is a powerful ally.

It is often impossible to send foremen on courses before the introduction of work study into an organisation. An excellent introduction to the general idea of methods improvement, provided its elementary nature and limited scope are recognised, is the training within industry (T.W.I.) job methods course. This course, which is available in practically all countries, is a means of opening minds to the idea of change and of challenging established practices.

The two other courses in the basic syllabus of T.W.I. (job relations and job instruction) are also of value when the application of work study to an enterprise is contemplated. As we have already seen, the first impact of work study is apt to impose considerable strains on relations within the organisation unless very careful steps have been taken to prepare for it. Job relations introduces the idea of handling people with tact and understanding instead of trying to impose one's
The Human Factor

will by virtue of one's superior position. Job instruction is an elementary course on how to teach people to do their jobs. Both courses can be of great value to supervisors and work study men alike in their work of changing attitudes and retraining operatives in improved methods of working. Proper instruction in all these matters can greatly ease the introduction of work study.¹

The work study man will only retain the friendship and respect of the foreman if he shows from the beginning that he is not trying to usurp his place. The following rules must be observed:

1. The work study man must never give a direct order to a worker. All instructions must be given through the foreman. The only exception to this is in matters connected with methods improvements where the worker has been ordered by the foreman to carry out the instructions of the work study man.

2. Workers asking questions calling for decisions outside the technical field of work study should always be referred to their foreman.

3. The work study man should never allow himself to express opinions to a worker which may be interpreted as critical of the foreman (however much he may feel like it!). If the worker later quotes to the foreman ("... but Mr. _____ said..."), there will be trouble!

4. The work study man must not allow the workers to “play him off” against the foreman or to use him to get decisions altered which they consider harsh.

5. The work study man should seek the foreman’s advice in the selection of jobs to be studied and in all technical matters connected with the process (even if he knows a great deal about the process). Remember, the foreman has to make it work from day to day.

6. At the start of every investigation the work study man should be introduced to the workers concerned by the foreman. The work study man should never try to start on his own.

This list of “Do’s” and “Don’t’s” may look frightening but is mainly common sense and good manners. The workers in any shop can only have one boss—their foreman—and everything must be done to uphold his authority. Of course, once the work study man and the foreman have worked together and understand one another there can be some relaxation, but that is a matter of judgment, and any suggestion for relaxation should come from the foreman.

A great deal of space has been given to the relations between the work study man and the foreman because it is the most difficult of all the relationships, and it

¹ An example of a course in work study for supervisors is given in Appendix 3. The job relations and job instruction courses may be given in parallel with this.
must be good. One of the best methods of ensuring that this is so is to provide both parties with the proper training.

4. WORK STUDY AND THE WORKER

Work study was in the past abused by so many people—mostly those who had little or nothing to do with it—that it was generally supposed that it might strain relations between workers and management. If the relationship is already a bad one almost anything will strain it, because the workers will be suspicious of everything the management does. Equally, if the workers have confidence in the sincerity and integrity of the management, almost any sound technique will be accepted and can be made to work.

In point of fact, work study, when properly applied, tends to improve industrial relations. There are several reasons why this should be so, namely—

(1) The mere fact that a member of the management (which is what the work study man is, although in a staff position) takes the trouble to come to the worker and to discuss his job and its problems with him arouses his interest.

(2) In most of the western countries, including the United States, the work study man has often been the pioneer of the new enlightened management. It is probably true to say that the arrival of a work study specialist (usually a consultant) in a shop is the first time that many workers have ever seen a well educated man working on the shop floor among them. The impact on the worker is often very great. Here is a sort of “boss” he had never imagined existed, who does not shout at him and who seems to know more than the foreman, hitherto regarded as the fountainhead of all wisdom. Little wonder if in quite a short time the worker starts going to the work study man for decisions and help. This situation is very familiar to all consultants and is one which they have to take great pains to avoid. It can be largely avoided if the shop supervision has received at least the training already suggested.

(3) If work study is properly applied and workers and their representatives are kept fully informed of all that is being done, with all study sheets readily available for inspection, a feeling of confidence will develop.

(4) Work study improves the flow of work and the supply of material. Workers are usually glad to be rid of interruptions so that they can get on with their jobs, especially if they are on piecework.

There are, however, some important factors which may cause workers to resist the introduction of work study.

(1) There may be strong resistance to changes in method proposed following method study, especially from older, skilled workers. Indeed, it may
prove impossible to get some workers to change to new methods. If the methods they use and their output are reasonably satisfactory they will have to be left alone, changes being taught to new workers only.

Skilled workers who have been at their trades for many years believe themselves masters of their crafts, as indeed they usually are. If changes are demanded of them—even if they are shown how they will increase productivity and improve quality—they will tend to resist those changes. This is partly because human beings naturally dislike change (unless they make the change themselves), but also because these changes shake their confidence in their own ability as craftsmen and may lower their prestige in the eyes of their fellows. The work study man, in discussing his work, has to make it very clear that most of what he is doing does not usually affect the craft part of the job or the process but eliminates movements wasted in picking up and putting down, fetching and carrying. By doing this, the craftsman is enabled to devote more time to the really skilled part of his job.

(2) Many workers resent being timed; this may be due to either a suspicion of the stopwatch—which can usually be dispelled if its use is properly explained—or simply that having someone standing watching them worries them. Here the position which the work study man takes up and the way in which he goes about it is extremely important. He must take care to allow the worker to become accustomed to his presence before attempting to record times.

It is not usually possible or even necessary to give instruction in work study to individual workers, beyond explaining the general purpose of it, but workers’ representatives should be given fuller explanations and, preferably, the same courses as the foremen. If they have such training at the same times as representatives of management they will see that nothing is being concealed. In courses run by the I.L.O. productivity missions to both Israel and India trade unionists attended the same courses as the trainees sent by companies. Nothing breeds suspicion like attempts to hide what is being done; nothing dispels it like frankness, whether in answering questions or in showing information obtained from studies. Work study honestly applied has nothing to hide.

(3) There is often a fear that redundancy may arise out of the results of work study, leading either to unemployment or transfer to another department.

This is a real problem which must be faced and discussed by the management and the unions so that a proper policy can be arrived at. It is possible, however, to overstress it. In most undertakings in developing countries—and even in industrially advanced ones—great improvements in productivity can generally be effected through the application of work study to improve plant utilisation and operation, make more effective use of space, and secure greater economy of materials, before the question of raising the productivity of the labour force need be pressed. In many cases it may actually pay to increase the number of workers
serving a given piece of plant if, by doing so, the percentage of time per shift
during which the plant is running can be increased. This is especially true where
wages are low. The importance of studying the productivity of all the resources of
the enterprise and not confining the application of work study to the productivity
of labour alone cannot be overemphasised. It is important to note that, quite apart
from any fear of redundancy, workers naturally resent efforts being made to im-
prove their output or efficiency while they can see glaring inefficiency on the part
of the management going unrectified. What is the use of halving the time a worker
takes to do a certain job by well-applied method study and giving him output
standards set by work measurement if he is constantly being held up by lack of
materials or machine breakdowns due to bad planning by the management?

An excellent practice, which wherever it has been introduced has helped to
allay workers’ suspicions of the possible effects of work study and has provided a
ready means of two-way communication between the workers and the work study
team, is that of inviting the workers in a section about to be studied to nominate
one of their number to join the team for the duration of the studies. The workers’
nominee is given the same basic training as the regular work study men receive,
and takes part with them in making studies on the shop floor and in compiling
time standards. He remains a member of his normal working group throughout
the period of his secondment to the work study team, drawing neither more nor
less pay than he did before, and after work study in the section has been completed
he returns to his normal duties. He thus remains a nominee of the workers through-
out, able to keep them informed about what is going on in terms which they will
understand. Since he receives neither additional pay nor advancement he cannot
be suspected of having been “bought” by the management.

If the workers’ nominee is to take his part as a member of the study team and
understand fully all that goes on, it is essential that he should have had sufficient
education to be able to comprehend work study procedures. This requirement,
which has to be made clear to the workers in the section before they make their
nomination, often imposes a limitation on the adoption of this highly commendable
practice in countries where the workforce is largely illiterate. However, it is often
possible to find a worker of adequate attainments to be the workers’ liaison man
for the whole works, staying with the study team for a longer period, even if
transient nominees from each section studied cannot be obtained. It is essential,
however, that the workers’ nominee be acceptable to the workers themselves, and
be trusted by them.

5. THE WORK STUDY MAN

We have talked a great deal in the preceding sections about what is required
from the work study man, suggesting by our requirements a human who is almost
too good to be true. The ideal man for the job is likely to be found very rarely,
and if he is he will quickly leave the ranks of work study men to rise to greater
heights. Nevertheless, there are certain qualifications and qualities which are
essential for success.
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Education.

The minimum standard of education for anyone who is to take charge of work study application in an enterprise is a good secondary education with matriculation or the equivalent school-leaving examination. It is unlikely that anyone who has not had such an education will be able fully to benefit from a full work study training course, although there may be a few exceptions, since certain people have special aptitudes for this type of work.

Practical Experience.

It is desirable that candidates for posts as work study specialists should have had practical experience in the industries in which they will be working. This experience should include a period of actual work at one or more of the processes of the industry. Having worked at a manual job will enable them to understand what it means to do a day's work under the conditions in which the ordinary workers with whom they will be dealing have to work. Practical experience will also command respect from foremen and workers. The exception is the technical graduate who has served an apprenticeship in the engineering industry, as this provides a background which enables a man to adapt himself to most other industries.

Personal Qualities.

Anyone who is going to undertake improvements in methods should have an inventive turn of mind, capable of devising simple mechanisms and devices which can often save a great deal of time and effort, and should be able to gain the cooperation of the engineers and technicians in developing them. The type of man who is good at this is not always so good at human relations, and in some large companies the methods department is separated from the work measurement department, although both are under the same chief. It is, however, unlikely that they will be separated in most of the countries with which this book is mainly concerned.

The following are essential qualities:

- **Sincerity and honesty.**

  The work study man must be sincere and he must be honest; only in this way will he gain the confidence and respect of those with whom he has to deal.

- **Enthusiasm.**

  He must be really keen on his job, believe in the importance of what he is doing and be able to transmit his enthusiasm to the people around him.
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- **Interest in and sympathy with people.**
  
  He must be able to get along with people at all levels. To get along with people it is necessary to be interested in them and able to see their points of view.

- **Tact.**
  
  Tact in dealing with people comes from understanding people and not wishing to hurt their feelings by unkind or thoughtless words, even when these may be justified. Without tact no work study man is going to get very far.

- **Good appearance.**
  
  He must be neat and tidy and look efficient. This will inspire confidence in him among the people with whom he has to work.

- **Self-confidence.**
  
  This can only come with good training and experience of applying work study successfully. The work study man must be able to stand up to top management, foremen, trade union officials or workers in defence of his opinions and findings, and do so in such a way that he will win respect and not give offence.

  These personal qualities, particularly the ability to deal with people, can all be further developed with the right training. Far too often this aspect of the training of work study men is neglected, the assumption being that, if the right man is selected in the first place, that is all that requires to be done. In most work study courses more time should be given to the human side of applying work study.

  It will be seen from these requirements that the results of work study, however "scientifically" arrived at, require to be applied with "art", just like any other management technique. In fact, the qualities which go to make a good work study man are the same qualities which go to make a good manager. Work study is an excellent training for young men destined for higher management. People with these qualities are not easy to find, but the careful selection of men for training as work study specialists will repay itself in the results obtained, in terms both of increased productivity and of improved human relations in the factory.

  Having described the background against which work study is to be applied, we can now turn to the question of applying it, starting with method study. Before doing so, however, some attention must be given to some general factors which have considerable bearing on its effect, namely the conditions under which the work is done in the area, factory or workshop concerned.
WORKING CONDITIONS

1. GENERAL

The first thing to do in attempting to improve methods of work in a factory or elsewhere is to ensure that the conditions under which the workers have to perform their tasks are such that they can do so without strain. This was emphasised by the first I.L.O. productivity mission to India in its report. It was the experience of this mission that productivity could often be increased simply by improving the working conditions, before method study techniques were applied. After all, it is little use making elaborate investigations into the improvement of working methods if lighting is so bad that operatives have to strain their eyes to see what they are doing or if the atmosphere is so hot and humid, or so charged with noxious fumes, that they have constantly to go into the open air to refresh themselves. Bad working conditions were listed among the main causes of ineffective time due to shortcomings of the management. Not only is time lost in the manner described but an excessive amount of bad work is caused which means waste of material and loss of output.

Bad working conditions are uneconomic. Often quite small improvements can produce marked increases in productivity. It must be remembered that the general working conditions in a shop or factory affect everyone working there, including supervisory staff. Method study and work measurement applied to a single operation may bring about a 100 per cent. increase in productivity—for that operation. The extent to which this affects the productivity of the shop as a whole depends on the number of operators working on similar jobs and how long
the job lasts, but it may mean an over-all rise of only a fraction of 1 per cent. Improved lighting, ventilation or heating may easily result in an immediate increase for the whole shop of 5 per cent. It can take a lot of work study to produce a 5 per cent. rise in a large shop on varied work!

The former head of one of the largest work study departments in the world\(^1\) said on many occasions: "Do not use a spoon when a steam shovel is needed." In other words, it is no use improving the layout of an individual workplace or the methods of the worker, using refined techniques and saving seconds on an operation, when hours are being lost through bad working conditions throughout the shop or factory. In terms of increased productivity the "steam shovel" of improved working conditions may be worth many "spoonfuls" of detailed method study.

Physical working conditions depend on many factors: the site of the building, the type of construction, layout, ventilation, temperature, lighting, sanitation, the nature of the floors and stairs, equipment installed, etc.

Detailed discussion of the siting of factories and of their construction is out of place here, since to change them if they are unsatisfactory involves considerable capital expenditure and other considerations which are outside the scope of this book. The question of factory layout, with particular reference to productivity, will be dealt with in Chapter 9. We are concerned here primarily with the conditions which surround the worker as he does his job, conditions which affect his physical well-being and thus his efficiency as a producer.

In taking this view we have not lost sight of the fact that he is a human being. Indeed, it is because the worker is a human being first and foremost, and a producer second, that his working efficiency is so much affected by the environment in which he has to work. Unhealthy and unhappy workers, doing their jobs under conditions of physical or mental strain, are inefficient producers—unlike machines, which are relatively indifferent to their surroundings.

2. CLEANLINESS\(^2\)

This is the first requirement for healthy workers, and one which usually costs little to fulfil.

It is essential to health that all factory shops and rooms should be kept in a sanitary condition. Accumulations of dirt should be removed daily from all workrooms, passages and staircases.

Spitting is especially dangerous to health. Notices expressly forbidding spitting on the floor, walls, or stairs should be posted in all parts of the factory. Where it

\(^1\) That of Imperial Chemical Industries, Ltd., in the United Kingdom.

Working Conditions

is necessary to provide spittoons they should be sufficient in number, hygienic and properly cleaned and disinfected at least once every working shift. Receptacles for waste and refuse should be so constructed that they cannot leak and can be conveniently and thoroughly cleaned, and should be maintained in sanitary condition. Sweepings and waste should be removed, if possible, outside working hours and in such a way as to avoid risk to health.

Particular care must be taken to rid workrooms and shops of rats, insects and other vermin, as these are amongst the worst carriers of disease. In districts where malaria is endemic all workplaces should, as far as possible, be screened against mosquitoes.

The need for proper sanitary accommodation should not have to be stressed and will not be dealt with here. Details of minimum requirements are to be found in the I.L.O. Model Code already referred to.

3. DRINKING WATER AND HYGIENE

Adequate supplies of clean and cooled drinking water from a reliable and regularly tested source should be made freely available at convenient locations close to all workplaces.

This is particularly important in areas where the quality of the water from piped supplies is suspect and on open worksites where workers may otherwise be tempted to refresh themselves from pools and streams liable to pollution. In such situations it is imperative to enforce strict discipline to ensure that only designated areas are used for latrines and sanitary purposes. During intensive studies on manual earth-moving operations carried out on a large dam site in India it was found that most of the workers, including those enjoying the best diets and feeding communally, were infested with intestinal parasites and had been apparently so infested for a considerable time. When such conditions are present or suspected it will not be enough merely to provide clean drinking water: employers should consider it part of their responsibilities to make available suitable medicaments to combat the infestations.

4. HOUSEKEEPING

Housekeeping, when used in reference to a factory or workroom, is a general term embracing cleanliness, tidiness and general state of repair. Cleanliness has already been dealt with; in this section we shall deal with tidiness.

Tidiness in the workshop is an aid to productivity as well as a means of reducing accidents. If gangways are not kept clear of stacks of material and other obstructions, time is lost in moving obstacles when materials are being transported.

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1 Ibid., Regulation 214.
Working Conditions

to and from workplaces or machines. In shops working on batch production complete batches of work in progress can be mislaid for hours if the floor is littered, and much time and energy can be wasted by foremen, production staff and workers in trying to find them.

The accumulations of odd lengths of raw materials, work in progress, jigs and tools (sometimes no longer in use), etc., which clutter up the floors and benches of many factories represent hard cash. Very large sums of money which could more profitably be used to finance the day-to-day working of the firm in place of bank loans or other forms of credit are often tied up in material, raw or half-finished, in shops and stores, quite apart from the space (for which rent, taxes and depreciation are being paid) which could be released for productive use. Keeping the amount of material in the shops to a minimum is thus an important way of reducing costs and increasing productivity. A large and famous engineering firm in the United Kingdom was able some years ago to find £750,000 to finance extensions by having a thorough clear-up of material on the floors of its shops. Many smaller firms could make useful savings by following suit.

Gangways must be kept clear. On concrete or wooden floors they should be marked with painted lines at least 5 cm (2 in.) broad. Gangways on earth floors may be marked by pegs with white- or yellow-painted tops driven well into the ground at frequent intervals. Nothing should be allowed to project over these lines into the gangways. Storage areas should be similarly marked off, with materials stacked neatly within them, accompanied by identifying labels or markings where necessary.

It is a rule of method study—and of materials handling—that nothing should be put on the floor of the shop unless absolutely necessary, as it only has to be picked up again at some time or other.

In the same way tools, jigs, fixtures and other equipment should not be left lying about the shop or workplace but should be returned to store or placed on racks conveniently located about the working area.

5. LIGHTING

In a covering letter to the 1953 edition of a publication entitled *American Standard Practice for Industrial Lighting* the Director of the Bureau of Labor Standards says: “Good lighting speeds production. It is essential to the health, safety and efficiency of workers. Without it eye damage will occur, accidents and spoilage of material will increase and production will slow down.”

This is no exaggeration. It is common sense to suppose that, especially where fine work is being done, insufficient light will reduce the productivity of the worker on account of the slowing up of the performance of the job, the repeated rests

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Working Conditions

that have to be taken and the increase in spoiled work, quite apart from any injury to the worker's eyes.

The efficiency of lighting depends on its quantity and its quality. Factors determining quality include glare, diffusion, direction and uniformity of distribution, colour and brightness.

Recommended practice in the United States for quantity values of illumination is shown in table 2.

TABLE 2. GENERAL RECOMMENDED VALUES OF ILLUMINATION

<table>
<thead>
<tr>
<th>Task Category</th>
<th>Current recommended practice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(foot candles in service, i.e. on task or 75 cm (30 in.) above floor)</td>
</tr>
<tr>
<td>Most Difficult Seeing Tasks</td>
<td>200-1000²</td>
</tr>
<tr>
<td>Finest Precision Work</td>
<td></td>
</tr>
<tr>
<td>Involving: Finest Detail; Poor Contrasts; Long Periods of Time</td>
<td></td>
</tr>
<tr>
<td>Such as: Extra-fine Assembly; Precision Grading; Extra-fine Finishing</td>
<td></td>
</tr>
<tr>
<td>Very Difficult Seeing Tasks</td>
<td>100</td>
</tr>
<tr>
<td>Precision Work</td>
<td></td>
</tr>
<tr>
<td>Involving: Fine Detail; Fair Contrasts; Long Periods of Time</td>
<td></td>
</tr>
<tr>
<td>Such as: Fine Assembly; High-Speed Work; Fine Finishing</td>
<td></td>
</tr>
<tr>
<td>Difficult and Critical Seeing Tasks</td>
<td>50</td>
</tr>
<tr>
<td>Prolonged Work</td>
<td></td>
</tr>
<tr>
<td>Involving: Fine Detail; Moderate Contrasts; Long Periods of Time</td>
<td></td>
</tr>
<tr>
<td>Such as: Ordinary Bench Work and Assembly; Machine Shop Work; Finishing of Medium-to-Fine Parts; Office Work</td>
<td></td>
</tr>
<tr>
<td>Ordinary Seeing Tasks</td>
<td>30</td>
</tr>
<tr>
<td>Involving: Moderately Fine Detail; Normal Contrasts; Intermittent Periods of Time</td>
<td></td>
</tr>
<tr>
<td>Such as: Automatic Machine Operation; Rough Grinding; Garage Work Areas; Switchboards; Continuous Processes; Conference and File Rooms; Packing and Shipping</td>
<td></td>
</tr>
<tr>
<td>Casual Seeing Tasks</td>
<td>10</td>
</tr>
<tr>
<td>Such as: Stairways; Reception Rooms; Washrooms and Other Service Areas; Active Storage</td>
<td></td>
</tr>
<tr>
<td>Rough Seeing Tasks</td>
<td>5</td>
</tr>
<tr>
<td>Such as: Hallways; Corridors; Passageways; Inactive Storage</td>
<td></td>
</tr>
</tbody>
</table>

2 Obtained with a combination of general lighting plus specialised supplementary lighting. Care should be taken to keep within the maximum brightness ratios (indicated in table 3) and to avoid glare when light-coloured materials are involved.
Working Conditions

Glare is bad for the eyes and for production alike. Direct glare may be reduced by decreasing the brightness of the light sources, increasing the brightness of the area around the source of glare or increasing the angle between the source of glare and the line of vision. Windows admitting bright sunlight can be shaded or white-washed; lamps for general lighting can be placed high above the normal line of vision and the quantity and brightness of their light can be limited. They should be fitted with reflectors properly designed to control the dispersal of light and provide a cut-off angle to prevent glare. Reflected glare from shiny surfaces such as ceilings and walls can be cut down by reducing the brightness of light sources, screening or diffusing the light or reducing contrasts by raising the level of the general lighting, or by using matt paint. As a rule general lighting should be evenly distributed. Faint shadows are desirable for distinguishing objects, but sharp shadows should be avoided.

Perception of a detail depends largely on the brightness difference between the detail and its background. The greater the difference, the easier is the detail seen. Some recommended maximum brightness ratios are given in table 3.

<table>
<thead>
<tr>
<th>TABLE 3. RECOMMENDED MAXIMUM BRIGHTNESS RATIOS1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between tasks and adjacent surroundings .......... 5 to 1</td>
</tr>
<tr>
<td>Between tasks and more remote surfaces .......... 20 to 1</td>
</tr>
<tr>
<td>Between light sources (or sky) and surfaces adjacent to them .......... 40 to 1</td>
</tr>
<tr>
<td>Anywhere within the environment of the worker .......... 80 to 1</td>
</tr>
</tbody>
</table>

The colour and reflectance of room walls, ceiling and floor, as well as of equipment, determine the brightness pattern and thus influence seeing. Recommended reflectance values are given in table 4.

<table>
<thead>
<tr>
<th>TABLE 4. RECOMMENDED REFLECTANCE VALUES1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of surface</td>
</tr>
<tr>
<td>Ceiling</td>
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<tr>
<td>Walls</td>
</tr>
<tr>
<td>Desk and bench tops</td>
</tr>
<tr>
<td>Machines and equipment</td>
</tr>
<tr>
<td>Floors</td>
</tr>
</tbody>
</table>

As a general rule daylight is preferable to artificial lighting, but where daylight is inadequate artificial light must be used to supplement or replace it. Where factories receive daylight through windows or skylights it will almost always be necessary to control the lighting by means of blinds, shades, overhangs or sun-breaks.

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1 Based on tables published in Safety in Industry: Illumination for Safety, op. cit.
Working Conditions

Whatever system of lighting is used it must be properly maintained and kept clean. In many factories a great deal of light is lost through dirt.

Suitable lighting should also be provided in all stairways, exits from work-places and passages to these.¹

While it is realised that it may not be possible in all countries and at all times to attain the standards recommended above, perhaps because of the lack of suitable equipment, they should be aimed at by those responsible for the design and equip-ment of factories and other working areas. Their attainment will be found to be well worth while in terms of improved productivity.

6. VENTILATION, HEATING AND COOLING²

General ventilation is required for the health and comfort of the workers, and is thus a factor in their efficiency. Members of the first I.L.O. productivity mission to India reported that in some of the factories and mills which they entered little had been done to mitigate the effects of heat by proper ventilation, and as a result of this a great deal of time was lost by workers having to go outside in order to recover from the “unbearable working conditions”.

Excessively high or excessively low temperatures and inadequate ventilation reduce productivity through sickness, discomfort and lowered vitality of the workers. The main cause of discomfort occasioned by working in a badly ventilated shop is not, as is often supposed, the greater concentration of carbon dioxide (CO₂) in the air but the reduced rate of heat loss from the body to the surroundings.

The effective temperature or cooling power of the air depends on—

the rate of air improvement;
air temperature;
humidity.

These three factors together with radiation enable the effective temperature to be computed.

Ventilation may be natural or artificial or a combination of the two. Air conditioning is employed chiefly to combat extremes of temperature.

Clean fresh air should be supplied to enclosed workplaces at such a rate as to effect a complete change of air a number of times per hour varying from six for sedentary workers to ten for active workers. There should be at least 11.5 cubic metres (400 ft³) of air space per person employed in a workroom.

² Ibid., Regulations 20-24.
Working Conditions

All dust, fumes, gases, vapours or mists generated and released in industrial processes should as far as possible be removed at their points of origin and not be permitted to spread throughout the atmosphere of the workrooms.

The speed of movement of the air in enclosed workplaces should not exceed 15 metres (50 ft) per minute while the premises are being artificially heated or 45 metres (150 ft) per minute during the hot season. The temperature and humidity of the air should be suitable for the work being performed.

Practical means of achieving desirable atmospheric conditions are described in a pamphlet issued by the Factory Department of the United Kingdom Ministry of Labour and National Service, in which optimum air temperatures are given for summer and winter and for given ranges of humidity. These will have to be adjusted for other climates. The most important single factor affecting comfort is the wet-bulb temperature, which should be kept below 70°F (21°C) if possible.

This, of course, is never possible in textile mills, where the humidity has to be kept high. Under such conditions the movement of air becomes doubly important, otherwise working becomes extremely uncomfortable. The I.L.O. mission to Pakistan, working in the cotton mills, emphasised this from its personal experience.

One of the most important instruments for daily use in factories where excessive heat and humidity are likely to occur is the wet kata thermometer, which gives a direct reading of the “cooling power” of the environment. Every work study man should understand its use.

The efficiency of natural ventilation depends largely on outside conditions, which often vary widely. It is often least efficient when ventilation is needed most. It is also difficult to control.

Where natural ventilation is not enough, mechanical ventilation by means of fans must be employed. This may be an exhaust system (extraction of air from the shop); an induction system (blowing in of air), using plenum ducting to conduct the air to where it is wanted, or a combination of both. The advantage of plenum ducting is that better control of the air movement is possible. Many plenum ducting systems serve the twin purposes of heating and ventilation, but where the working conditions are hot the ducting may be employed to convey cooling air. Air flow should be in one direction wherever possible and fans should all face in the same direction so as to act with and not against each other. In hot, dry climates air is often cooled relatively cheaply by blowing it through water sprays before leading it to the shops.

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2 Appendix 7 contains notes on the use of the wet kata thermometer.

3 As this book is intended to be used mainly in countries where cooling rather than heating is important, it is not felt necessary to deal with systems of heating. References to standard works on the subject will be found in the book list.
<table>
<thead>
<tr>
<th>Process and workplace</th>
<th>Surface</th>
<th>Cool conditions</th>
<th>Average conditions</th>
<th>Warm conditions</th>
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<tbody>
<tr>
<td>Clean processes:</td>
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<td>small and medium-</td>
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</tbody>
</table>

Source: Commonwealth of Australia, Department of Labour and National Service: *Colour in Industry*, Industrial Data Sheets, Series C1., No. 11.1.: *Typical Colour Schemes*.
Working Conditions

7. COLOUR

Some reference should be made to the use of colour as a factor influencing the workers' feelings of heat or coolness. It has been shown that in temperate conditions workers' comfort has been enhanced by repainting the walls and furnishings of the workplace in colours designed to give a feeling of warmth or cold. Suggestions for colour schemes with other valuable psychological effects besides the one noted above, are to be found in table 5 on page 65. It is worth bearing in mind that, when the time comes to repaint workshops and offices, it costs little or no more to use pleasing colours than drab ones, and that to do so is a visible sign of the management's desire to make conditions pleasanter for the workers.

8. NOISE

Noise is also a factor of importance in relation to the efficiency of workers. It is a frequent cause of fatigue, irritation and thus loss of output. Anyone who has tried to do calculations or work demanding intense concentration in noisy surroundings, such as a weaving shed or a machine shop full of automatic machines, knows how exhausting noise can be, even though he may be able to shut it out from his consciousness for a while. Particularly disturbing is intermittent noise, such as that of road drills (used for digging machinery foundations), riveting guns, drop hammers or heavy presses. Exposure to exceptionally loud noise can cause permanent damage to hearing.

The following example illustrates the restraints on output which noise can impose. A group of experienced workers assembling 80 temperature regulators produced some 60 faults. The room in which they were working was next to a noisy boiler shop. They were moved to a quieter place, where they did 110 regulators in the time formerly required to do 80, and with only seven faults.

Protection against loud but unavoidable noise may be provided by earplugs, of which there are several types, ranging from wads of cotton wool to specially moulded plastic devices. In very bad situations, as for instance when work is done in close proximity to jet engines, "ear defenders"—thick, cup-like muffs enclosing the whole ear—are essential to prevent permanent damage to hearing.

There are various ways of reducing noise, including the mounting of noisy machines on absorbent bases. This is, however, a job for the specialist. Sound insulation may be achieved by lining the walls and ceilings of rooms with suitable material, the choice of which will depend on a variety of factors, including the degree of noise reduction required, fire risk, and the need for cleaning.

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Noise may be excessive in intensity or frequency or both. The maximum tolerable intensity may be taken to be in the region of 90 decibels, but lower intensities may be objectionable at very high frequencies.

Noise can be measured by instruments called audiometers, of which different types exist.

9. THE WORKPLACE: WORKING SPACE AND SEATING

It is obvious that no worker can be efficient unless he has sufficient space in which to work, to lay down his tools and materials, and to move without being hindered by fellow workers, other machines or stacks of material. Although in certain conditions the health of the worker may be affected by overcrowding at the workplace, in general the question is more one of efficiency and will be dealt with more fully in the chapters on the application of method study.

Prolonged standing at work is one of the most common sources of avoidable discomfort or fatigue, and seats should be provided to enable workers—men and women—to sit at their work whenever practicable or, where work cannot be done sitting, to rest at intervals. It is generally realised that the prevention of unnecessary fatigue promotes efficiency. Progressive firms are usually alive to the advantages of good seating but many employers do not pay enough attention to the subject. Workers are often made to stand continuously, either because of the mistaken idea that they will thus work harder and better, or simply because it has always been the tradition to do so.

Older workers tell stories of having foremen kick from under them boxes on which they were sitting at their work in the days of their apprenticeships. The idea that to sit is to idle dies hard in some quarters. Yet it seems only common sense to conserve energy so that there may be more available to put into productive work. On one job studied during the work of the first I.L.O. productivity mission in India a marked increase in output was obtained simply by providing a seat for the worker. Students of psychology may wonder how much of the increase was due to the worker’s pleasure in being noticed and favoured, but it is worth remembering that once a worker has increased his tempo of work, whatever the cause, that tempo is likely to be maintained if conditions remain the same.

In many parts of the world, including India and Pakistan, the natural position is squatting, and many workers prefer this position to sitting. Indeed, even when provided with seats some workers, especially the older ones, may be found squatting on them. Note must be taken of such traditional or local preferences, and where squatting is regarded as more comfortable the workplace must be studied so as to make it as convenient as possible for that position.

Recommendations regarding the provision of seats are to be found in the
10. THE PREVENTION OF ACCIDENTS

Quite apart from the human suffering caused by industrial accidents, the total loss of production resulting from an accident is more than is often realised. A survey of United Kingdom engineering works published in 1952 showed that, for every 1,000 workmen employed in such works, accidents occur on the average as follows:

• **Every day**
  Ten new injuries receive surgical treatment and 40-50 minor injuries occur.

• **Every week**
  One serious accident will cause a loss of 10-20 working days.

• **Every two years**
  One major accident will cause permanent and serious disability.

• **Every ten years**
  One fatal accident will occur.

The total time lost directly as a result of reportable factory accidents in the United Kingdom during 1951 amounted to nearly 30,000 man-years. In addition to this direct loss, even greater amounts of time were lost indirectly as a result of accidents. According to sample studies, the time lost by foremen, staff and other workers in giving assistance to the victims of accidents amounted to four times as much as that lost by the victims themselves. In addition, large costs were incurred for spoilt materials and tools as well as for medical aid and compensation.

All the time lost through accidents adds to the time taken to produce a given quantity of goods or services and consequently results in decreased productivity. Remember that productivity is likely to be increased quite as much by cutting out unnecessary loss of time as by improvements to processes and methods.

---

Apart from the direct loss of time when work is stopped because of an accident, unsafe conditions slow up working since operatives have to be on their guard and so move and work with less assurance than they would if the dangers did not exist. Shafting, driving-belts and moving machinery positioned near to where people work or pass are specially hazardous. They should all be fenced off or be furnished with guards to prevent accidental contact.

One of the I.L.O. missions visited a weaving shed where the main driving shafts were located in troughs in the floor at the back of the looms. These troughs were covered over at the gangways and immediately behind the looms where it was necessary to work, but were open and quite unguarded where the belts emerged. Anyone working at the back of the looms changing a beam or looking for a broken end had to take the utmost care; a step to one side would result in a fall into the trough to almost certain death. This had in fact happened more than once. The care with which the operatives moved when behind the looms was obvious even to casual visitors and undoubtedly caused a loss in output, if only by slowing up the changing of beams and thus prolonging the changeover time. Dissatisfaction on the part of the workers with these conditions had given rise to unrest, with consequent further loss of production. A quite small outlay on guard rails would have paid for itself in a very short time.

In one field alone—that of materials handling—method study can play a notable part in reducing accidents, simply by reducing the number of times and the distance over which material is handled.

In 1966 no less than 78,626 notifiable factory accidents in Great Britain happened while materials were being handled. Method study tries to eliminate all unnecessary handling, and it is certain that if all the jobs in which these 78,626 accidents occurred had been properly studied beforehand a very high percentage, perhaps as high as 50 per cent., of the accidents would never have happened, because the goods would not have been handled—method study would have eliminated the operation.

The prevention of accidents must be tackled first by eliminating possible causes, technical and human. The means of doing so are too varied to be dealt with here. They include compliance with technical regulations and standards, a high level of supervision and maintenance, the fostering of good industrial relations, care for the workers' health and welfare, training all members of the works to observe safety regulations and safe practices, posting warning notices and using distinctive colours to draw attention to objects likely to prove dangerous.

1 See Chapter 9.
Working Conditions

There is a large body of literature on this subject from many countries, references to some of which are to be found in the book list at the end of this volume. Attention is drawn especially to the Model Code of Safety Regulations for Industrial Establishments, published by the I.L.O., and already quoted in this chapter.

11. FIRE PREVENTION

Accidental fires are likely to be very frequent in hot and dry countries, especially in certain industries. The prevention of fires is primarily a matter of the proper training of all concerned and the strict enforcement of fire prevention regulations, such as rules against smoking in places where it would be hazardous. Prevention is always better than cure, but the provision of adequate extinguishers and other appliances maintained in good condition is essential. It is also important that all members of the management and supervisors should be instructed on exactly what they are to do should a fire occur and that workers should also know what to do and the exits by which they should leave their shops. Fire, especially in a multi-storey building, can cause panic which may be more dangerous to life and limb than the fire itself. If everyone knows exactly what to do panic can be avoided. Although in this discussion we are concerned mainly with the safety of personnel, it may be of interest to note that in Sweden the financial losses of industry each year owing to fire are greater than the total annual depreciation of plant and equipment.

12. NUTRITION

The subject of working conditions should not be closed without some reference to the amounts and nutritional values of the diets which the workers ordinarily consume. In many countries the workers' daily intake of foodstuffs is little more than their bodies need merely to sustain life and is quite insufficient to support prolonged expenditure of energy in the performance of heavy manual work. In many instances malnutrition is chronic, having existed for years, perhaps throughout the whole of the workers' lives. Nor is it uncommon to find that traditional diets, while perhaps adequate in quantity to supply the calories needed, are lacking in one or other or several of the constituents necessary for balanced nutrition.

In such circumstances it cannot be expected of workers that they will be able to sustain the heavy energy outputs which are commonplace with well-fed, healthy operatives, quite apart from any climatic difficulties there may be to contend with. Work study men should always be on their guard, when setting standards, for nutritional deficiencies and their probable accompaniment, widespread debility, perhaps even disease.

The effect which adequate feeding can have on manual workers was shown most strikingly during a large-scale investigation into the outputs of workers employed on earth-moving operations in India, carried out in 1962 and 1963.
Work study techniques were used to measure output, and it was found that the loads carried, the hours actually worked, and the outputs achieved by the best groups of workers exceeded those of the others by at least a third. Careful study showed that the differences were not attributable to differences in ages, experience, working methods or statures between the groups, but were solely occasioned by the differences in feeding habits. Most of the working groups fed themselves, in families, their women looking after the shopping and cooking. The better groups, however, came from districts where it was the traditional practice for the employers to feed their workers communally, as part of their conditions of employment. The communally-fed workers had for years eaten diets which gave them half as many calories again as the others, and which were moreover well balanced, with adequate proteins.

Employers in many parts of the world provide meals for workers in their factories, usually at subsidised rates. Even in countries where malnutrition is uncommon it is found to be good business to do so, for other reasons, but in areas where workers are ordinarily underfed the provision of at least one good, balanced meal a day may be an essential prerequisite to productivity improvement as well as a civic responsibility. Many employers do more than this, providing also food shops within their premises where the workers can buy foods of consistent quality for home consumption, at fair prices.

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PART TWO

METHOD STUDY
1. DEFINITION AND OBJECTS OF METHOD STUDY

Method study has already been defined in Chapter 4, but the definition is worth repeating at this point.

Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

The term "method study" is being increasingly used in place of "motion study", although the latter was intended by its inventor, Frank Gilbreth, to cover
almost exactly the same field. *Industrial Engineering Terminology*, published by the American Society of Mechanical Engineers, gives separate definitions for “method study” and “motion study”, the latter being confined to hand and eye movements at the workplace. However, “motion study” is used in most United States textbooks with the same meaning as “method study”.

The objects of method study are—

- The improvement of processes and procedures.
- The improvement of factory, shop and workplace layout and of the design of plant and equipment.
- Economy in human effort and the reduction of unnecessary fatigue.
- Improvement in the use of materials, machines and manpower.
- The development of a better physical working environment.

There are a number of method study techniques suitable for tackling problems on all scales from the layout of complete factories to the smallest movements of workers on repetitive work. In every case, however, the method of procedure is basically the same and must be carefully followed.

### 2. BASIC PROCEDURE

In examining any problem there should be a definite and ordered sequence of analysis. Such a sequence may be summarised as follows:

1. **DEFINE** the problem.
2. **OBTAIN** all the facts relevant to the problem.
3. **EXAMINE** the facts critically but impartially.
4. **CONSIDER** the courses open and decide which to follow.
5. **ACT** on the decision.
6. **FOLLOW UP** the development.

We have already discussed the basic procedure for the whole of work study, which embraces the procedures of both method study and work measurement. Let us now examine the basic procedure for method study, selecting the proper steps. They are as follows:
LEARN THESE SEVEN STEPS BY HEART

These are the seven essential stages in the application of method study: none can be excluded. Strict adherence to their sequence, as well as to their content, is essential for the success of an investigation. They are shown diagrammatically on the chart in figure 8.

Do not be deceived by the simplicity of the basic procedure into thinking that method study is easy and therefore unimportant. On the contrary, method study may on occasion be very complex, but for purposes of description it has been reduced to these few simple steps.

3. SELECTING THE WORK TO BE STUDIED

Some Factors Involved

When considering whether a method study investigation of a particular job should be carried out certain factors should be kept in mind. These are—

1. Economic considerations.
2. Technical considerations.
3. Human reactions.
FIGURE 8. METHOD STUDY
(Reproduced and adapted by permission of Imperial Chemical Industries Ltd., London)

METHOD STUDY
to improve methods of production

Select
work which can be studied with economic advantage
Define scope of study

Record

Plant Layout by means of
Charts
Outline process
Flow process
- man type
- material type
Multiple activity
Travel

Other Means
Flow diagram
String diagram
Models

Work Place by means of
Charts
Two handed
Simo
PMTS
Multiple activity
Cyclographs
Chromocyclographs
Film analysis
Motion photography

Examine the Facts Critically

Purpose - Place - Sequence - Person - Means

Seek Alternatives

Find Points

Eliminate
Combine or Change
Simplify

Develop
a record of an improved method

Re-examine
that record to establish

Planning and control
Materials handling
General environment and working conditions
Plant layout

The Best Method under Prevailing Circumstances

Define
process or procedure - layout - equipment - materials - quality - instruction - working conditions

Install
the improved method
plan - arrange - implement

Maintain
Verify at regular intervals that the improved method as defined is in fact in use

Mechanical aids
Manual controls
and visual instruments
Equipment design
Jigs and fixtures
Local working conditions

To achieve
Improved factory and workplace layout
Improved design of equipment
Better working conditions
Reduction of fatigue resulting in improved use of Material
Plant and equipment
Manpower

Higher Productivity

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1. **Economic considerations** will be important at all stages. It is obviously a waste of time to start or to continue a long investigation if the economic importance of the job is small, or if it is one which is not expected to run for long. The first questions must always be: “Will it pay to begin a method study of this job?”, and: “Will it pay to continue this study?”

Obvious early choices are—

“**bottlenecks**” which are holding up other production operations;

**movements of material over long distances** between shops, or operations involving a great deal of manpower and equipment;

**operations involving repetitive work** using a great deal of labour and liable to run for a long time.

2. **Technical considerations** will normally be obvious. The most important point is to make sure that adequate technical knowledge is available with which to carry out the study. Examples are—

(a) The loading of unfired ware into kilns in a pottery. A change in method might bring increased productivity of plant and labour, but there may be technical reasons why a change should not be made. This demands the advice of a specialist in ceramics.

(b) A machine tool constituting a bottleneck in production is known to be running at a speed below that at which the high-speed cutting tools will operate effectively. Can it be speeded up, or is the machine itself not robust enough to take the faster cut? This is a problem for the machine-tool expert.

3. **Human reactions** are among the most difficult to foretell, since mental and emotional reactions to investigation and changes of method have to be anticipated. Experience of local personnel and local conditions should reduce the difficulties. Trade union officials, workers’ representatives and the operatives themselves should be instructed in the general principles and true objectives of method study. If, however, the study of a particular job appears to be leading to unrest or ill-feeling leave it alone, however promising it may be from the economic point of view. If other jobs are tackled successfully and can be seen by all to benefit the people working on them opinions will change and it will be possible, in time, to go back to the original choice.

Method study will be more readily accepted by the workers if the first subjects selected are ones which are unpopular, such as dirty jobs or those calling for the lifting of heavy weights. If these jobs can be improved and the unpleasant features removed from them method study will be seen to be reducing the effort and fatigue of the workers and will be welcomed accordingly.
TABLE 6. TYPICAL INDUSTRIAL PROBLEMS AND APPROPRIATE METHOD STUDY TECHNIQUES

<table>
<thead>
<tr>
<th>Type of Job</th>
<th>Examples</th>
<th>Recording technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete sequence of manufacture</td>
<td>Manufacture of an electric motor from raw material to dispatch. Transformation of thread into cloth from preparation to inspection. Receipt, packing and dispatch of fruit.</td>
<td>Outline process chart Flow process chart Flow diagram</td>
</tr>
<tr>
<td>Factory layout: movement of materials</td>
<td>Movements of a diesel engine cylinder head through all machining operations. Movements of grain between milling operations.</td>
<td>Outline process chart Flow process chart–material type Flow diagram Travel chart Models</td>
</tr>
<tr>
<td>Factory layout: movement of workers</td>
<td>Labourers servicing spinning machinery with bobbins. Cooks preparing meals in a restaurant kitchen.</td>
<td>Flow process chart–man type String diagram Travel chart</td>
</tr>
<tr>
<td>Handling of materials</td>
<td>Putting materials into and taking them out of stores. Loading lorries with finished products.</td>
<td>Flow process chart–material type Flow diagram String diagram</td>
</tr>
<tr>
<td>Workplace layout</td>
<td>Light assembly work on a bench. Typesetting by hand.</td>
<td>Flow process chart–man type Two-handed process chart Multiple activity chart Simo chart PMTS chart Cyclegraph Chronocyclegraph</td>
</tr>
<tr>
<td>Gang work or automatic machine operation</td>
<td>Assembly line. Operator looking after semi-automatic lathe.</td>
<td>Multiple activity chart Flow process chart–equipment type</td>
</tr>
<tr>
<td>Movements of operatives at work</td>
<td>Female operatives on short-cycle repetition work. Operations demanding great manual dexterity.</td>
<td>Films Film analysis Simo chart Memotion photography Micromotion analysis</td>
</tr>
</tbody>
</table>
Definition and Objects: Selection of Jobs

The Field of Choice

The range of jobs which may be tackled by method study in any factory or other place where materials are moved or manual work is carried on (including routine office work) is usually a very wide one. Table 6 gives the general field of choice, starting from the most comprehensive investigation covering, possibly, the whole operation of the plant and working down to the study of the movements of the individual worker. Beside each type of job are listed the recording techniques with which it may be attacked. It should be pointed out that, in the course of a single investigation, two or more of these techniques, even (though rarely) all of them, may be used. These techniques will be described in subsequent chapters.

When selecting a job for method study it will be found helpful to have a standardised list of points to be covered. This prevents factors being overlooked and enables the suitability of different jobs to be easily compared. A sample list\(^1\) is given below which is fairly full, but lists should be adapted to individual needs.

1. *Product and operation.*
2. *Person who proposes investigation.*
5. *Particulars of the job.*

(a) How much is\(^2\) (many are) produced or handled per week?
(b) What percentage (roughly) is this of the total produced or handled in the shop or plant?
(c) How long will the job continue?
(d) Will more or less be required in future?
(e) How many operatives are employed on the job—
   (i) directly?
   (ii) indirectly?
(f) How many operatives are there in each grade and on each rate of pay?
(g) What is the average output per operative (per team) per day?
(h) What is the daily output compared with the output over a shorter period? (e.g. an hour)
(i) How is payment made? (team work, piecework, premium bonus, time rate, etc.)

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\(^1\) This list has been adapted from one given in Anne G. Shaw: *The Purpose and Practice of Motion Study* (Manchester, Columbine Press, 1960—second edition).

\(^2\) For bulk materials measured in tons, pounds, feet, kilogrammes, metres, etc.
(j) What is the daily output—
(i) of the best operator?
(ii) of the worst operator?

(k) When were production standards set?

(l) Has the job any specially unpleasant or injurious features?
Is it unpopular (a) with workers? (b) with supervisors?

   (a) What is the approximate cost of plant and equipment?
   (b) What is the present machine utilisation index?¹

7. Layout.
   (a) Is the existing space allowed for the job enough?
   (b) Is extra space available?
   (c) Does the space already occupied need reducing?

8. Product.
   (a) Are there frequent design changes causing modifications?
   (b) Can the product be altered for easier manufacture?
   (c) What quality is demanded?
   (d) When and how is the product inspected?

9. What savings or increase in productivity may be expected from a method improvement?
   (a) Through reduction in the "work content" of the product or process.
   (b) Through better machine utilisation.
   (c) Through better use of labour.
   (Figures may be given in money, man-hours or machine-hours or as a percentage.)

Item 4 deserves some comment. It is important to set clearly defined limits to the scope of the investigation. Method study investigations so often reveal scope for even greater savings that there is a strong temptation to go beyond the immediate objective. This should be resisted, and any jobs shown up as offering scope for big improvements through method study should be noted and tackled separately.

Such a list will prevent the work study man from going first for a small bench job which will entail a detailed study of the worker's movements and yield a saving

¹ Machine utilisation index = the ratio of Machine Running Time to Machine Available Time. See Appendix 5 for further explanation.
Definition and Objects: Selection of Jobs

of a few seconds per operation, unless the job is one that is being done by a large number of operatives, so that the total saving will significantly affect the operating costs of the factory. It is no use playing around with split seconds and inches of movement when a great waste of time and effort is taking place due to bad shop layout and the handling of heavy materials.

Finally, remember the adage: “Do not use a spoon when a steam shovel is needed.”

Subject to the considerations listed on pages 81–82, tackle first the job most likely to have the greatest over-all effect on the productivity of the enterprise as a whole.
RECORD, 
EXAMINE, 
DEVELOP

1. RECORDING 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.

The usual way of recording facts is to write them down. Unfortunately this method is not suited to the recording of 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 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, so as to be readily understood by all method study men, in whatever factory or country they may be working.

The most commonly used of these recording techniques are charts and diagrams. There are several different types of standard charts available, each with its own special purpose. 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—

### Table 7. The Most Commonly Used Method Study Charts and Diagrams

<table>
<thead>
<tr>
<th>A. <strong>CHARTS</strong> indicating process SEQUENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outline Process Chart</td>
</tr>
<tr>
<td>Flow Process Chart—Man Type</td>
</tr>
<tr>
<td>Flow Process Chart—Material Type</td>
</tr>
<tr>
<td>Flow Process Chart—Equipment Type</td>
</tr>
<tr>
<td>Two-Handed Process Chart</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. <strong>CHARTS</strong> using a TIME SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Activity Chart</td>
</tr>
<tr>
<td>Simo Chart</td>
</tr>
<tr>
<td>P.M.T.S. Chart</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. <strong>DIAGRAMS</strong> indicating movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Diagram</td>
</tr>
<tr>
<td>String Diagram</td>
</tr>
<tr>
<td>Cyclegraph</td>
</tr>
<tr>
<td>Chronocyclegraph</td>
</tr>
<tr>
<td>Travel Chart</td>
</tr>
</tbody>
</table>

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(a) Those which are used to record a process sequence—that is, a series of events or happenings in the order in which they occur—but which do not depict the events to scale; and

(b) 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 were listed in table 6 in the last chapter against the types of job for which they are most suitable. They are shown again in table 7, which lists them in the two groups given above, and also lists the types of diagram commonly used.

Diagrams are used to indicate movement more clearly than charts can do. They usually do not show all the information recorded on charts, which they supplement rather than replace. Among the diagrams is one which has come to be known as the Travel Chart, but despite its name it is classed as a diagram.

Process Chart Symbols

The recording of the facts about a job or operation on a process chart is greatly facilitated by the use of a set of five standard symbols, which together serve to represent all the different types of activity or event likely to be encountered in any factory or office. They thus form 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:

\[ \text{OPERATION} \]

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.

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1 The symbols used throughout this book are those recommended by the American Society of Mechanical Engineers and adopted in the British Standard Glossary of Terms in Work Study. There is another set of symbols still in fairly common use, an abbreviated form of the set originated by F. B. and L. M. Gilbreth. It is recommended that the A.S.M.E. symbols should be adopted in preference to the Gilbreth.

2 For a definition of "process" see p. 20, footnote 2.
Record, Examine, Develop

\[ \text{INSPECTION} \]

Indicates an inspection for quality and/or a 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 adding or subtracting material, as in the case of an assembly. An operation may equally well be a preparation for any activity which furthers the completion of the product.

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—

\[ \text{TRANSPORT} \]

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 operator at the work station during an operation or an inspection. This symbol is used throughout this book whenever material is handled on or off trucks, benches, storage bins, etc.

\[ \text{TEMPORARY STORAGE OR DELAY} \]

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 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 stores under some form of authorisation; or an item is retained for reference purposes.

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

In this book, for simplicity, temporary storage or delay will be referred to shortly 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 operator at the same work station the symbols for those activities are combined, e.g. the circle within the square represents a combined operation and inspection.

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 over-all 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 alongside the symbol, and the time allowed for it, where known, is also added.

An example of an outline process chart is given in figure 10. In order that the reader may obtain a firm grasp of the principles involved, the assembly repre-
sented on this chart is shown in a sketch (figure 9) and the operations charted are
given in some detail below.

Example of an Outline Process Chart:
Assembling a Switch Rotor

The assembly drawing (figure 9) shows the rotor for a slow make-and-break switch.

FIGURE 9. SWITCH ROTOR ASSEMBLY

It consists of—

a spindle (1);
a plastic moulding (2);
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 in-
spections undergone by the principal unit or component of the assembly (or com-
pound 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.

1 This example is adapted from W. Rodgers: Methods Engineering Chart and Glossary (Nottingham,
England, School of Management Studies, Ltd.).
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 (.025 hours).

*Operation 2*  
Face opposite end on the same machine (.010 hours).  
After this operation the work is sent to the inspection department for—
Record, Examine, Develop

**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 (.070 hours). The work is now sent to the burring bench.

**Operation 4** Remove burrs at the burring bench (.020 hours). 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 (.0015 hours).

**Operation 6** Cadmium plating (.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 (.080 hours).

**Operation 8** Drill cross-hole (for the stop pin) and burr on two-spindle drill press (.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 further 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 specially 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 10 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 (.02 hours).

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 (.025 hours).

**Operation 11** Remove the “pip” on a linisher (.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 (.0015 hours).

**Operation 13** Cadmium plating (.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 (.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, alongside 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 10 so that the main sequence of charting may be seen more clearly.

Figure 11 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.

**FIGURE 11. SOME CHARTING CONVENTIONS**

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 next pages the flow process chart will be described and its use as a tool of methods improvement illustrated.
FIGURE 12. FLOW PROCESS CHART: ENGINE STRIPPING, CLEANING AND DEGREASING

<table>
<thead>
<tr>
<th>DISTANCE (m.)</th>
<th>SYMBOL</th>
<th>ACTIVITY</th>
<th>TYPE OF ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>☐</td>
<td>In old-engine stores</td>
<td>Non-productive</td>
</tr>
<tr>
<td>24</td>
<td>☐</td>
<td>Picked up engine by crane (electric)</td>
<td>Non-productive</td>
</tr>
<tr>
<td>30</td>
<td>☐</td>
<td>Transported to stripping bay</td>
<td>Non-productive</td>
</tr>
<tr>
<td>1.5</td>
<td>☐</td>
<td>Engine stripped</td>
<td>Productive</td>
</tr>
<tr>
<td>3</td>
<td>☐</td>
<td>Main components cleaned and laid out</td>
<td>Non-productive</td>
</tr>
<tr>
<td>6</td>
<td>☐</td>
<td>Parts carried to degreasing basket</td>
<td>Non-productive</td>
</tr>
<tr>
<td>12</td>
<td>☐</td>
<td>Loaded for degreasing by hand-operated crane</td>
<td>Non-productive</td>
</tr>
<tr>
<td>6</td>
<td>☐</td>
<td>Unloaded into degreaser</td>
<td>Non-productive</td>
</tr>
<tr>
<td>12</td>
<td>☐</td>
<td>Degreased</td>
<td>Productive</td>
</tr>
<tr>
<td>9</td>
<td>☐</td>
<td>Lifted out of degreaser by crane</td>
<td>Non-productive</td>
</tr>
<tr>
<td>12</td>
<td>☐</td>
<td>Transported away from degreaser</td>
<td>Non-productive</td>
</tr>
<tr>
<td>12</td>
<td>☐</td>
<td>Unloaded to ground</td>
<td>Non-productive</td>
</tr>
<tr>
<td>12</td>
<td>☐</td>
<td>To cool</td>
<td>Non-productive</td>
</tr>
<tr>
<td>12</td>
<td>☐</td>
<td>Transported to cleaning benches</td>
<td>Non-productive</td>
</tr>
<tr>
<td>9</td>
<td>☐</td>
<td>All cleaned parts placed in one box</td>
<td>Non-productive</td>
</tr>
<tr>
<td>76</td>
<td>☐</td>
<td>All cleaned parts placed in one box</td>
<td>Non-productive</td>
</tr>
<tr>
<td>76</td>
<td>☐</td>
<td>Transformed to engine inspection section</td>
<td>Non-productive</td>
</tr>
<tr>
<td>237.5</td>
<td>☐</td>
<td>Stored temporarily awaiting inspection</td>
<td>Non-productive</td>
</tr>
</tbody>
</table>

(Adapted from an original)
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 — Man type: A flow process chart which records what the worker does.

Flow process chart — Material type: A flow process chart which records what happens to material.

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. In fact, it is usual to have only one printed form of chart for all three types, the heading bearing the words “Man/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

---

1 It is customary to use the active voice of verbs for entries on man type charts, and the passive voice on material type and equipment type charts. This convention is more fully explained in Section 3 of Chapter 10.
is given in figure 12. This chart is adapted from one made by two members of a course given by an I.L.O. expert at the Dapodi workshops of the Bombay State Transport Authority. 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. Man type charts are discussed in Chapter 10.

When flow process charts are being made regularly, it is convenient to use printed or stencilled sheets similar to that shown in figure 13. This also ensures that the studyman does not omit any essential information. In figure 13 the operation just described on the chart in figure 12 is set down again.

Before going 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 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).

3 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 standardising work or improving methods. An untidy chart will always make a bad impression and may lead to errors.

4 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 13):

   (a) The name of the product, material or equipment charted, with drawing numbers or code numbers.

1 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.
**FIGURE 13. FLOW PROCESS CHART—MATERIAL TYPE: ENGINE STRIPPING, CLEANING AND DEGREASING**

*(Original Method)*

### FLOW PROCESS CHART

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>PRESENT</th>
<th>PROPOSED</th>
<th>SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPERATION</strong></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TRANSPORT</strong></td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DELAY</strong></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INSPECTION</strong></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STORAGE</strong></td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### METHOD: PRESENT/PROPOSED

DISTANCE (m) 237.5

### LOCATION: Degreasing Shop

TIME (man-min) |

### OPERATOR(S): A.B. C.D.

CLOCK Nos. 1234 571

### CHARTED BY: R.F. Unwalla & K.V. Rao

DATE: 11.11.55

### DESCRIPTION

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>QTY.</th>
<th>DISTANCE (m.)</th>
<th>TIME (min)</th>
<th>SYMBOL</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored in old-engine store</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine picked up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported to next crane</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td>Electric crane</td>
</tr>
<tr>
<td>Unloaded to floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picked up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported to stripping bay</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unloaded to floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine stripped</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main components cleaned and laid out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Components inspected for wear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection report written</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parts carried to degreasing basket</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded for degreasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported to degreaser</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td>Hand crane</td>
</tr>
<tr>
<td>Unloaded into degreaser</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degreased</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifted out of degreaser</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported away from degreaser</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unloaded to ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To cool</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported to cleaning benches</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>By hand</td>
</tr>
<tr>
<td>All parts cleaned completely</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All cleaned parts placed in one box</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td>By hand</td>
</tr>
<tr>
<td>Awaiting transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All parts except cylinder block and heads loaded on trolley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported to engine inspection section</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td>Trolley</td>
</tr>
<tr>
<td>Parts unloaded and arranged on inspection table</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder block and head loaded on trolley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported to engine inspection section</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td>Trolley</td>
</tr>
<tr>
<td>Unloaded to ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored temporarily awaiting inspection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL 237.5 4 21 3 1 1

*(Adapted from the original)*

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98
(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 later study the chart and who may have been accustomed to using different symbols. It is convenient to show these as part of a table summarising the activities in the present and proposed methods (see figure 13).

(h) A summary of distance, time and, if desired, cost of labour and material, for comparison of old and new methods.

(5) 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 work-piece under consideration, that is, 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 work-piece and set it in position ready to be worked on. In the example in figure 12 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.

- **"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; 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 object 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 organisation exists, for example: the act of selling in a shop; the act of typing in an office.) These are "productive" activities; all others, however necessary, may be considered as "non-productive" (see figure 12). The first activities to be challenged must therefore be those which are obviously "non-productive", including storages and delays which represent capital tied up that could be used to further the business.
The Primary Questions

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

the PURPOSE for which
the PLACE at which
the SEQUENCE in which
the PERSON by whom
the MEANS by which

the activities are undertaken

with a view to

ELIMINATING
COMBINING
REARRANGING or
SIMPLIFYING

those activities.

In the first stage of the questioning technique, the Purpose, Place, Sequence, Person, Means of every activity recorded is systematically queried, and a reason for each reply is sought.

The primary questions therefore are—

PURPOSE: \[
\begin{align*}
\text{What} & \quad \text{is actually done?} \\
\text{Why} & \quad \text{is the activity necessary at all?}
\end{align*}
\]

ELIMINATE unnecessary parts of the job.

PLACE: \[
\begin{align*}
\text{Where} & \quad \text{is it being done? Why is it done at that particular place?}
\end{align*}
\]

COMBINE wherever possible or
REARRANGE the sequence of operations for more effective results.

SEQUENCE: \[
\begin{align*}
\text{When} & \quad \text{is it done? Why is it done at that particular time?}
\end{align*}
\]

PERSON: \[
\begin{align*}
\text{Who} & \quad \text{is doing it? Why is it done by that particular person?}
\end{align*}
\]

SIMPLIFY the operation.

MEANS: \[
\begin{align*}
\text{How} & \quad \text{is it being done? Why is it being done in that particular way?}
\end{align*}
\]
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 over the existing method.

Thus, during this second stage of questioning, having asked already, about every activity recorded, what is done and why it is done, the method study man 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 heads: 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.

Example: Engine Stripping, Cleaning and Degreasing

Let us now consider how the members of the course who made the flow process chart in figure 12 set about examining the record of facts which they had obtained in order to develop an improved method. Before doing so we shall transfer the same record to a standard flow process chart form (figure 13) with the necessary information on the operation, location, etc., duly filled in.

This form, like all the forms in this book, is designed so that it can be prepared on a standard typewriter. The arrangement of the symbols in the columns is to enable those used most to be closest together.

To help the reader to visualise the operation a flow diagram showing the layout of the degreasing shop and the path taken by the engine in its journey from the old-engine stores to the engine-inspection section is given in figure 14. It is evident from this that the engine and its parts follow an unnecessarily complicated path.

Examination of the flow process chart shows a very high proportion of “non-productive” activities. There are in fact only four operations and one inspection, while there are 21 transports and three delays. Out of 29 activities, excluding the original storage, only five can be considered as “productive”.

Detailed examination of the chart leads to a number of questions. For example, it will be seen that an engine being transported from the old-engine stores has to change cranes in the middle of its journey. Let us apply the questioning technique to these first transports:

Q. **What** is done?

A. The engine is carried part of the way through the stores by one electric crane, is placed on the ground and then picked up by another which transports it to the stripping bay.

Q. **Why** is this done?

A. Because the engines are stored in such a way that they cannot be directly picked up by the monorail crane which runs through the stores and degreasing shop.

Q. **What else** might be done?

A. The engines could be stored so that they are immediately accessible to the monorail crane, which could then pick them up and run directly to the stripping bay.
FIGURE 14. FLOW DIAGRAM: ENGINE STRIPPING, CLEANING AND DEGREASING

**ORIGINAL METHOD**

1 = Store
2 = Stripping
3 = Degreaser
4 = Cooling
5 = Cleaning
6 = Locker
7 = Tool Cabinet
8 = Paraffin Wash
9 = Charge Hand

--- Mono-rail

**PROPOSED METHOD**

A = Store
B = Engine Stand (Stripping)
C = Basket
D = Degreaser
E = Cleaning
F = Motor
G = Locker
H = Charge Hand
I = Bench

--- Mono-rail
Q. What **should** be done?
A. The above suggestion should be adopted.

In the event this was adopted and resulted in the elimination of three “transports” (see figure 15).

Let us continue the questioning technique.

Q. **Why** are the engine components cleaned **before** going to be degreased since they are again cleaned after the grease is removed?
A. The original reason for this practice has been forgotten.

Q. **Why** are they inspected at this stage when it must be difficult to make a proper inspection of greasy parts and when they will be inspected again in the engine-inspection section?
A. The original reason for this practice has been forgotten.

This answer is one very frequently encountered when the questioning technique is applied. On many occasions activities are carried out for reasons which are important at the time (such as temporary arrangements to get a new shop going quickly in the absence of proper plant and equipment) and are allowed to continue long after the need for them has passed. If no satisfactory reason can be given for their continuance such activities must be ruthlessly eliminated.

The next questions which present themselves refer to the loading into the degreaser. Here it appears to have been necessary to transport the parts 3 metres in order to put them into the degreaser basket. **Why** can the degreaser basket not be kept near at hand? Can the parts not be put straight into the degreaser basket as the engine is dismantled?

The above suffices to illustrate how the questioning technique can be applied. The questions and answers may sometimes look rather childish as they are set out above, but in the hands of an experienced investigator the questioning is very rapid. Sticking to the very rigid sequence ensures that no point is overlooked. And, of course, starting with the most-searching scrutiny of the operation itself—

**What** is done? and **Why** is it necessary?

ensures that time is not wasted on details if the whole operation should not be necessary, or if its fundamental purpose could be achieved in some better way.
### FIGURE 15. FLOW PROCESS CHART—MATERIAL TYPE: ENGINE STRIPPING, CLEANING AND DEGREASING

(Improved Method)

<table>
<thead>
<tr>
<th>CHART No. 2</th>
<th>SHEET No. 1</th>
<th>OF 1</th>
<th>Subject charted:</th>
<th>Used bus engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTIVITY:</td>
<td>Stripping, degreasing and cleaning prior to inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>METHOD:</td>
<td>PROPOSED/PROPOSED</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCATION:</td>
<td>Degreasing shop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPERATOR(S):</td>
<td>A.B. C.D.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHARTED BY:</td>
<td>R.F. Unwalla &amp; K.V.Rao</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPROVED BY:</td>
<td>L.M.B.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DATE:</td>
<td>11.11.55</td>
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<table>
<thead>
<tr>
<th>OPERATION</th>
<th>PRESENT</th>
<th>PROPOSED</th>
<th>SAVING</th>
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<tbody>
<tr>
<td>4</td>
<td>3</td>
<td>1</td>
<td></td>
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<tr>
<td>21</td>
<td>15</td>
<td>6</td>
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</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
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</table>

<table>
<thead>
<tr>
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<th>237.5</th>
<th>150.0</th>
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<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>TIME (man-min)</th>
<th>COST</th>
<th>LABOUR</th>
<th>MATERIAL</th>
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<tbody>
<tr>
<td>Storage in old-engine store</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Engine picked up</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Transported to stripping bay</td>
<td>55</td>
<td>Electric</td>
<td>Hoist on mono-rail</td>
<td></td>
</tr>
<tr>
<td>Unloaded on to engine stand</td>
<td>1</td>
<td>By hand</td>
<td>Hoist</td>
<td></td>
</tr>
<tr>
<td>Engine stripped</td>
<td>1.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Transported to degreaser basket</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Loaded into basket</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Transported to degreaser</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Unloaded from degreaser</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Transported from degreaser</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Unloaded to ground</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Allowed to cool</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Transported to cleaning benches</td>
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<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>All parts cleaned</td>
<td>6</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>All parts collected in special trays</td>
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<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Awaiting transport</td>
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<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Trays and cylinder block loaded on trolley</td>
<td>76</td>
<td>Trolley</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Transported to engine inspection section</td>
<td>76</td>
<td>Trolley</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Tiers slid on to inspection benches and blocks on to platform</td>
<td>76</td>
<td>Trolley</td>
<td>--</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>QTY.</th>
<th>DISTANCE (m.)</th>
<th>TIME (min)</th>
<th>SYMBOL</th>
<th>REMARKS</th>
</tr>
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<tbody>
<tr>
<td>Stored in old-engine store</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Engine picked up</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
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<td>55</td>
<td>Electric</td>
<td>Hoist on mono-rail</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Unloaded on to engine stand</td>
<td>1</td>
<td>By hand</td>
<td>Hoist</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Engine stripped</td>
<td>1.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
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<tr>
<td>Transported to degreaser basket</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Loaded into basket</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Transported to degreaser</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Unloaded from degreaser</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Transported from degreaser</td>
<td>4.5</td>
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<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Unloaded to ground</td>
<td>4.5</td>
<td>--</td>
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<td>--</td>
<td></td>
</tr>
<tr>
<td>Allowed to cool</td>
<td>4.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Transported to cleaning benches</td>
<td>6</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>All parts cleaned</td>
<td>6</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>All parts collected in special trays</td>
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<td>--</td>
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</tr>
<tr>
<td>Awaiting transport</td>
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<td>--</td>
<td></td>
</tr>
<tr>
<td>Trays and cylinder block loaded on trolley</td>
<td>76</td>
<td>Trolley</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Transported to engine inspection section</td>
<td>76</td>
<td>Trolley</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Tiers slid on to inspection benches and blocks on to platform</td>
<td>76</td>
<td>Trolley</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL** 150 3 15 2 1
3. DEVELOP THE IMPROVED METHOD

There is an old saying to the effect that to ask the right question is to be half way to finding the right answer. This is specially true in method study. From the very brief example of the use of the questioning sequence given above it will be seen that once the questions have been asked most of them almost answer themselves. Once the questions—

- What should be done?
- Where should it be done?
- When should it be done?
- Who should do it?
- How should it be done?

have been answered, it is the job of the method study man to put his findings into practice.

The first step in doing so is to make a record of the proposed method on a flow process chart so that it can be compared with the original method and can be checked to make sure that no point has been overlooked. This will also enable a record to be made in the “summary” of the total numbers of activities taking place under both methods, the savings in distance and time which may be expected to accrue from the change and the possible savings in money which will result. The improved method for the example discussed is shown charted in figure 15.

It will be seen from the summary that there have been considerable reductions in the number of “non-productive” activities. The number of “operations” has been reduced from four to three by the elimination of the unnecessary cleaning and the inspection carried out directly after it has also been eliminated. “Transports” have been reduced from 21 to 15 and the distances involved have also been cut from 237.5 to 150 metres, a saving of over 37 per cent. in the travel of each engine. In order not to complicate this example times of the various activities have not been given, but a study of the two flow process charts will make it evident that a very great saving in the time of operation per engine has been achieved.

No further example of a flow process chart is given in this chapter because flow process charts will be used later in the book in association with other techniques.
THE FLOW AND HANDLING OF MATERIALS

1. PLANT LAYOUT

It is sometimes desirable to know about the paths of movement of men and materials through the factory or working area during the process of manufacture or in the course of other activities. As a flow process chart alone will not give this information, it is useful to supplement it with other forms of recording, particularly the diagrams developed to indicate movement. Notable among these is the flow diagram. This is a diagram, substantially to scale, of the area covered by the process or activity, on which the location of the various points of activity and the paths of movement between them are shown.

Before going on to discuss in detail the flow diagram and its use, however, let us consider briefly some aspects of plant layout in different industries.
The Flow and Handling of Materials

Plant layout is the production of a floor plan for arranging the desired machinery and equipment of a plant, established or contemplated, in the way which will permit the easiest flow of materials, at the lowest cost and with the minimum of handling, in processing the product from the receipt of raw material to the dispatch of the finished product.¹

A great deal of time can be added to the total work content of a process by bad layout, which causes unnecessary movement of material and uses up the time and energy of the workers without adding anything to the completion of the job.

In many factories there has been no properly-thought-out change of layout since they were first opened. Benches, machines, pieces of plant and even whole departments have been added from time to time wherever space could be found. The result is that material often has to make long and roundabout journeys in the course of being processed.

Improving factory layout is part of the job of the work study man, but, since changes of layout usually mean moving plant, equipment and even pipes and cables, he must work in close co-operation with the works manager and plant engineer.

The extent to which the layout of the factory or working area is important to the productivity of the process or activities undertaken varies greatly from industry to industry. Equally variable is the extent to which it is possible to alter the layout once it has been established. These two factors must be firmly in the minds of all work study men who have occasion to study the flow of materials or the movements of workers about the plant.

2. THE IMPORTANCE OF LAYOUT IN VARIOUS INDUSTRIES

It may be said that the importance of attaining the best possible layout is directly proportional to—

- The weight, size or immobility of the product.

If the product is very heavy or difficult to handle, involving expensive equipment or a large amount of labour, it is most important that it should move as little as possible between operations.

The Flow and Handling of Materials

Examples: heavy castings in a foundry
          locomotive construction
          heavy diesel-engine manufacture.

Conversely, if the product or its components are very small and light, so that hundreds, or even thousands, representing, perhaps, several days' supplies, can be carried at one time, layout is comparatively unimportant.

Examples: watch parts
          radio valve parts.

- The complexity of the product.

If the product is made up of a very large number of parts, so that a great many people are likely to be employed in moving them from shop to shop, or between operations in the same shop, good layout becomes important.

Examples: aircraft manufacture
          assembly of motor cars.

- The length of the process time in relation to the handling time.

If the moving and handling time represents a large proportion of the total time of manufacture, any reduction in time of travel or handling of the product or its components will have a marked effect on the productivity of the factory, especially if the product, though possibly light, is bulky, so that only a few can be transported at a time.

Examples: press work in metal industries
          carton manufacture
          furniture making.

Conversely, if the process time is very long, as in certain machining operations in heavy engineering which may last for days, layout becomes less important.

Remember that when the process time is shortened by speeding up operations or by introducing high performance machinery, the ratio between handling time and process time is affected: handling time becomes relatively longer.

- The extent to which the process makes use of mass production methods.

Mass production methods of manufacture make extensive use of high-volume machinery, often operated automatically, so that relatively little labour is needed for the direct manufacturing processes. In consequence, a high proportion of the total factory labour force may be engaged in transporting the output, if the layout is not good.
The Flow and Handling of Materials

Examples: canned-food manufacture
cotton spinning
glass-bottle making.

3. POSSIBILITY OF ALTERING LAYOUT ONCE ESTABLISHED

The layout of manufacturing processes often depends to a great extent on technical considerations. Sometimes it can only be altered when a new plant is built. Examples of this are many chemical processes, such as fertiliser manufacture, heavy chemicals and the manufacture of synthetic fibres. In some industries the machinery is very heavy and may be impossible to move once it has been set in place. Drop hammers and heavy presses are examples. It is usually difficult and time-consuming to move textile machinery. On the other hand, most of the machines used in medium engineering—lathes, drills, milling machines and the like—can be moved without too much trouble and expense. In many plants in the United States and in some in the United Kingdom machine tools are not permanently fixed, but are moved around at intervals to form product lines as new products go into production. In the light industries such as clothing, radio assembly and paper-bag making, changing the layout of shops is a relatively simple matter. Where changes in layout involve any considerable work, however, the management and the works engineers will have to be convinced that real savings will be achieved before they will be prepared to sanction them.

4. SOME NOTES ON FACTORY LAYOUT

The layout of a factory should be such as to make the flow of work through it as easy as possible. In a factory making a single product it is simple to arrange the equipment so that each operation is next to the one before it in the manufacturing sequence, the product going from process to process without having to go back along the same path. In ideal conditions materials come in at one end of the factory, travel through it in a straight line and come out at the other as a finished product ready for dispatch.

Ideal conditions are not often possible in real life. There is no harm in the work travelling round the factory, provided that it follows an orderly path, and that the distances between successive operations are kept as short as possible so that the work moves steadily forward.

In factories where many products are made, or where the products are made up of many different parts, a good layout is more difficult to achieve, especially when batch quantities are small and there is a choice of processes. This situation is generally found at its worst in the engineering industry. A decision may have to be taken between having a "process" layout and a "product" layout.
A process layout is one in which all machines or processes of the same type are grouped together.

A product layout is one in which all machines or processes concerned in the manufacture of the same product or range of products are grouped together.

Most general engineering workshops are a mixture of the two types.

The following is a short list of the advantages and disadvantages of both.¹

- **Process Layout: Advantages and Disadvantages**

  1. The sequence of manufacturing is flexible. Machines can be kept busy most of the time. Machine breakdowns do not hold up a succession of operations; work can be transferred to other similar machines nearby.

  2. When varied products are required in low and medium quantities, the process layout will probably require less total investment in machines than a product layout would.

  3. Production volumes less than the rated or intended volume of output are probably less costly to produce with the process type of layout.

  But—

  4. More floor space is usually taken up with a process layout.

  5. The workers and supervisors must be capable of handling varied jobs. They will thus usually require more skills than operatives manning a product layout, and will take longer to train.

  6. There are no fixed paths along which all work must flow. Consequently there is more handling of materials; a larger volume of work in progress, and a more complicated system of production control is needed than that for a product layout.

- **Product Layout: Advantages and Disadvantages**

  1. Since the work flows along direct physical routes there are fewer delays and less handling is needed. A simpler production control system with less forms and records will suffice.

¹ There is not the space in this book to discuss in detail the advantages and disadvantages of each type. The notes given here are based on L. P. ALFORD and J. R. BANGS: *Production Handbook* (New York, The Ronald Press Company, 1964, second edition), sections 14 and 19.
FIGURE 16. A FLOW DIAGRAM: ASSEMBLING AND WELDING BUS SEATS

PLANT: S.T. Central Workshops, Poona
SHOP: Coach (Mfg.)
PROJECT: ASSEMBLY AND WELDING OF SEAT LEG TO SEAT FRAME

FLOW DIAGRAM (PRESENT METHOD)

DATE: 12.11.55
BY: R.P. KARANDIKAR K.N. PARAD

SCHEDULE
1 Store
2 Rack
3 Cutting
4 Marking hole centres
5 Drilling
6 Press
7 Correcting
8 Welding
9 Assembly
10 Painting

To PRESS
From PRESS
PASSAGE
Throughput time can be kept low: less floor space is occupied; the volume of work in progress can be kept down.

Manufacturing costs will be lower at high rates of production than they would be with a process layout.

Generally, less skill is required to operate the specialised machines, so that the training of inexperienced workers is easier.

But—

The capital investment in machines will probably be higher, because of the need to duplicate some of the machines on the different product lines.

When a product line runs light the manufacturing costs of the output tend to rise steeply, because of the high investment cost.

A single machine breaking down may shut down a whole production line.

An example of a changeover from process layout to product layout is given in section 9 of this chapter.

5. THE FLOW DIAGRAM

The flow diagram is used to supplement the flow process chart. It is a plan, substantially to scale, of the factory or shop, with the locations of machines, workplaces and working areas correctly depicted on it. As a result of observation in the shop the paths of movement of the materials, components or products under consideration are traced, sometimes using the process chart symbols to denote the activities carried out at the various stopping points.

Figure 16 shows a very simple flow diagram made in the workshops of the Bombay State Transport Authority under the guidance of a member of the I.L.O. productivity mission to India. It represents the movements of the material used in the assembly and welding of legs to frames for the seats of motor buses before the application of method study to the operation. A glance at it will show that there seems to be far too much travelling of material between workplaces. After studying flow diagrams and flow process charts of these activities, the distance travelled was reduced from 575 to 194 metres.

The Three-Dimensional Flow Diagram

This is a variation of the flow diagram used for the study of movement on several floors of a multi-storey building. It will be seen from the example given in figure 17 that it is the same in principle as the flow diagram described above. The three-dimensional flow diagram is particularly useful when studying spinning
The Flow and Handling of Materials

mills, flour mills and all factories where the material has to travel upwards or downwards through the building in the course of the process. It is also useful when recording movements in the rambling, multi-storied buildings which are often found to have been converted to factory use in the middle of cities. Ordinary flow diagrams of each floor can, of course, be made as well.

6. DEVELOPING THE NEW LAYOUT: THE USE OF TEMPLATES AND SCALE MODELS

The standard sequence of record and examine critically must be followed with the flow process chart when supplemented with a flow diagram. Once this has been done and wasted time and effort eliminated as far as practicable, it will be possible to develop the new layout. This will necessitate moving the points at which operations, inspections and storages take place around until the best layout—that most economical of distance and time—has been discovered. It is obviously impossible to do this with the actual equipment, except in the case of the very lightest. But it may be done most conveniently on the flow diagram itself.

The simplest method—and one which avoids covering the flow diagram with lines and erasures—is to cut out pieces of cardboard the size (to scale) of the various machines, benches and other pieces of equipment which it may be necessary to move in order to achieve the final layout. A scale of \( \frac{1}{4} \) in. = 1 ft or 2 cm = 1 m is convenient. These card pieces are known as “templates”. Do not forget to make templates for trucks and trolleys used in moving material around the working area; it may be necessary, when positioning machines or storage equipment, to make sure that gangways are wide enough for them to pass through or turn in. In making templates and scale plans make sure that the dimensions of all equipment are correct at the scale being used or, if anything, a little oversize; much time and effort may go for nothing if templates are cut out slightly on the small side and the space available in gangways and openings is overestimated in consequence. It is better to be on the safe side. Differently coloured cards may be used for different types of equipment such as machines, storage racks, benches or transport equipment. It is important to mark in doorways, pillars and other possible obstructions.

When trying out different arrangements templates can be held in place with ordinary pins or drawing pins; the former are easier to use if the templates are going to be moved about a lot. Thread may be used to indicate paths of flow if it is not wished to mark the diagram until the layout has finally been decided upon. The sketch in figure 18 shows templates being used.

Templates are being increasingly replaced by scale models of machines and equipment for purposes of examining existing layouts and developing improved ones. These are especially valuable when planning new shops or factories. They have the following advantages over the ordinary two-dimensional diagram:
The Flow and Handling of Materials

FIGURE 17. A THREE-DIMENSIONAL FLOW DIAGRAM

- Trucked 27 m to Elevator
- Lowered 5.2 m to Second Floor
- Drilled
- Conveyor 18 m to Miller
- Trucked 13 m to Drill Press
- Ground
- Inspection
- Turned
- Trucked 21 m to Lathe
- Conveyor 6 m to Inspection
- Conveyor 9 m to Grinder
- Trucked 6 m to Elevator
- Lowered 5.2 m to First Floor
- Trucked 19 m to Packing Room
- Painted
- Trucked 11 m to Shipping
- Trucked 9.5 m to Paint Room
- Packed
FIGURE 18. USING TEMPLATES TO DEVELOP A NEW LAYOUT

FIGURE 19. SIMPLE MODELS OF COMMON MACHINE TOOLS AND EQUIPMENT

A = Capstan lathe.
B = Spindle drill press.
C = Miller.
D = Tool stand.
E = Planer.
F = Fork lift truck.
G = Stillage.
HH = Pillars.
Models are easier to handle than templates.

The fact that heights are to scale as well as length and breadth of machines and other equipment is often of value, especially in the case of materials handling operations. When necessary, models of doorways, pipelines, overhead conveyors and even roof joists may be included in order to show clearances and any obstructions to shafting or to the movements of stacking trucks, motor vehicles or overhead travelling cranes.

Models are more valuable for demonstration and teaching purposes. People who have not been trained to read drawings find it much easier to see what a change will mean from a three-dimensional model than from an ordinary diagram. Models are most valuable for teaching the principles of layout and the handling of materials, as much as anything because everyone likes models; they are such fun to play with. People learn best when they are interested.

Models of machines and equipment need not be expensive, or elaborate, provided that they are made accurately to scale. The same warning as applies to templates applies to models. They can be made of wood and shaped roughly to the likeness of the equipment they represent (see figure 19) as long as care is taken to ensure that the over-all dimensions are correct. Stacks of material, bar stock and material handling equipment of all kinds can be represented. A colour code for different kinds of equipment can be used, e.g. green for production plant, yellow for material handling equipment, red for storage racks, and so on, the models being painted accordingly for ease of identification. Alternatively they may be painted the same colours as the actual items of equipment.

If the sheet representing the shop is stuck on to a thin steel sheet and small magnets are let into the models underneath, they will be very easy to move about and at the same time adherent enough to the sheet for the latter to be set vertically against a wall if desired.

Coloured threads may be used to represent paths of movement of various products or components in the same way as with the ordinary flow diagram.

Although simple wooden models serve quite well enough for the solution of practical layout problems, it is nowadays possible to obtain correct-to-scale reproductions of most common machine tools and many other items of industrial equipment. These beautifully made models are a delight to handle, and of course they look exactly like the machines they represent, which wooden models cannot always do. They are, however, costly.

---

1 This should usually be ¼ in. = 1 ft or 2 cm = 1 m as for templates.
7. EXAMPLE OF THE USE OF A FLOW DIAGRAM WITH A FLOW PROCESS CHART: RECEIVING AND INSPECTING AIRCRAFT PARTS

The flow diagram in figure 20 shows the original layout of the receiving department of an aircraft factory. The path of movement of the goods from the point of delivery to the storage bins is shown by the broad line. It will be noticed that, as in figure 17, the symbols for the various activities have been inserted at the proper places. This enables anyone looking at the diagram to imagine more readily the activities to which the goods are subjected.

**RECORD**

The sequence of activities is one of unloading from the delivery truck cases containing aircraft parts (which are themselves packed individually in cartons), checking, inspecting and marking them before putting them into store. These cases are slid down an inclined plane from the tail of the truck, slid across the floor to the “unpacking space” and there stacked one on top of another to await opening. They are then unstacked and opened. The delivery notes are taken out and the cases are loaded one at a time on a hand truck by which they are taken to the reception bench. They are placed on the floor beside the bench. After a short delay they are unpacked; each piece is taken out of its carton and checked against the delivery note. It is then replaced in its carton; the cartons are replaced in the case and the case is moved to the other side of the receiving bench to await transport to the inspection bench. Here the case is again placed on the floor until the inspectors are ready for it. The parts are again unpacked, inspected, measured and replaced as before. After a further short delay the case is transported to the marking bench. The parts are unpacked, numbered and repacked in the cartons and the case, which after another delay is transported by hand truck to the stores and there placed in bins to await issue to the assembly shops. The complete sequence has been recorded on a flow process chart (figure 21).

**EXAMINE critically**

A study of the flow diagram shows immediately that the cases take a very long and roundabout path in their journey to the bins. This could not have been seen from the flow process chart alone. The chart, however, enables the various activities to be recorded and summarised in a manner not conveniently possible on the diagram.

A critical examination of the two together, using the questioning technique, at once raises many points which demand explanation, such as:

---

1 This example has been taken, with some adaptation, from Simplification du Travail (the French version of a handbook produced by North American Aviation, Inc., Texas Division) (Liège, Editions Desoer).
FIGURE 20. FLOW DIAGRAM: INSPECTING AND MARKING INCOMING PARTS
(Original Method)
**FIGURE 21. FLOW PROCESS CHART: INSPECTING AND MARKING INCOMING PARTS**

(Original Method)

<table>
<thead>
<tr>
<th>Flow Process Chart</th>
<th>Man/Material/Equipment Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject charted:</td>
<td>Case of BX 487 Tee-pieces (10 per case in cartons)</td>
</tr>
<tr>
<td>Activity:</td>
<td>Receive, check, inspect and number tee-pieces and store in case</td>
</tr>
<tr>
<td>Method:</td>
<td>Present/Proposed</td>
</tr>
<tr>
<td>Location:</td>
<td>Receiving Dept.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty</th>
<th>Distance (m)</th>
<th>Time (min)</th>
<th>Symbol</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifted from truck; placed on inclined plane</td>
<td>1.2</td>
<td>10</td>
<td>2</td>
<td></td>
<td>2 labourers</td>
</tr>
<tr>
<td>Slid on inclined plane</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slid to storage and stacked</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Await unpacking</td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case unstacked</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lid removed; delivery note taken out</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placed on hand truck</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucked to reception bench</td>
<td>9</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Await discharge from truck</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case placed on bench</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartons taken from case: opened; checked</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>replaced contents</td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td>Storekeeper</td>
</tr>
<tr>
<td>Case loaded on hand truck</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>2 labourers</td>
</tr>
<tr>
<td>Delay awaiting transport</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucked to inspection bench</td>
<td>16.5</td>
<td>10</td>
<td></td>
<td></td>
<td>1 labourer</td>
</tr>
<tr>
<td>Await Inspection</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td>Case on truck</td>
</tr>
<tr>
<td>Tee-pieces removed from case and cartons:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspected to drawing; replaced</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
<td>Inspector</td>
</tr>
<tr>
<td>Await transport labourer</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>Case on truck</td>
</tr>
<tr>
<td>Trucked to numbering bench</td>
<td>9</td>
<td>5</td>
<td></td>
<td></td>
<td>1 labourer</td>
</tr>
<tr>
<td>Await numbering</td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td>Case on truck</td>
</tr>
<tr>
<td>Tee-pieces withdrawn from case and cartons:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>numbered on bench and replaced</td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td>Stores labourer</td>
</tr>
<tr>
<td>Await transport labourer</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>Case on truck</td>
</tr>
<tr>
<td>Transported to distribution point</td>
<td>4.5</td>
<td>5</td>
<td></td>
<td></td>
<td>1 labourer</td>
</tr>
<tr>
<td>Stored</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Description**

- **Operation:**
- **Transport:**
- **Delay:**
- **Inspection:**
- **Storage:**

**Location:** Receiving Dept.

**Operator(s):**

**Charted By:** B.C.

**Approved By:** T.H.

**Date:**

<table>
<thead>
<tr>
<th>Charted Date</th>
<th>Approved Date</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.11.48</td>
<td>5.11.48</td>
<td>$3.24</td>
</tr>
</tbody>
</table>

**COST**

- **Labour:** $3.24
- **Material:** $0

**Description**

- **Labour:** 2
- **Material:** $

**Remarks**

- **Labour:** 2
- **Material:** $3.24

**Total**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Present</th>
<th>Proposed</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>2</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td>7</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Inspection</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Distance (m):** 56.2

**Time (man-h.):** 217

**122**
Q. Why are the cases stacked to await opening when they have to be unstacked in 10 minutes?
   A. Because the delivery truck can be unloaded faster than work is cleared.

Q. What else could be done?
   A. The work could be cleared faster.

Q. Why are the reception, inspection and marking points so far apart?
   A. Because they happen to have been put there.

Q. Where else could they be?
   A. They could be all together.

Q. Where should they be?
   A. Together at the present reception point.

Q. Why does the case have to go all round the building to reach the stores?
   A. Because the door of the stores is located at the opposite end from the delivery point.

No doubt the reader who examines the flow diagram and the flow process chart carefully will find many other questions to ask. There is evidently much room for improvement. This is a real-life example of what happens when a series of activities is started without being properly planned. Examples with as great waste of time and effort can be found in factories all over the world.

- DEVELOP the improved method

The solution arrived at by the work study men in this factory can be seen in figures 22 and 23. It is clear that among the questions they asked were those suggested above, because it will be seen that the case is now slid down the inclined plane from the delivery truck and put straight on a hand truck. It is transported straight to the “unpacking space” where it is opened while still on the truck and the delivery note is taken out. It is then transported to the reception bench where, after a short delay, it is unpacked and the parts are put on the bench. The parts are counted and checked against the delivery note. The inspection and numbering benches have now been placed beside the reception bench so that the parts can be passed from hand to hand for inspection, measuring and then numbering. They are finally replaced in their cartons and repacked in the case which is still on the truck.
The Flow and Handling of Materials

**FIGURE 22. FLOW DIAGRAM: INSPECTING AND MARKING INCOMING PARTS**
(Improved Method)
**FIGURE 23. FLOW PROCESS CHART: INSPECTING AND MARKING INCOMING PARTS**

*(Improved Method)*

<table>
<thead>
<tr>
<th>Subject charted:</th>
<th>ACTIVITY</th>
<th>PRESENT</th>
<th>PROPOSED</th>
<th>SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case of BX 487 tee-pieces (10 per case in cartons)</td>
<td>OPERATION</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TRANSPORT</td>
<td>11</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>DELAY</td>
<td>7</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>INSPECTION</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>STORAGE</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**METHOD: PRESENT/PROPOSED**

<table>
<thead>
<tr>
<th>LOCATION: Receiving Dept.</th>
<th>DISTANCE (m)</th>
<th>66.2</th>
<th>32.2</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTIVITY: Receive, check, inspect and number tee-pieces; store in case</td>
<td>TIME (man-h.)</td>
<td>1.96</td>
<td>1.16</td>
<td>.80</td>
</tr>
<tr>
<td>METHOD:</td>
<td>DISTANCE (m)</td>
<td>56.2</td>
<td>32.2</td>
<td>24</td>
</tr>
<tr>
<td>OPERATOR(S)</td>
<td>COST per case</td>
<td>$3.24</td>
<td>$1.97</td>
<td>$1.27</td>
</tr>
<tr>
<td>CLOCK No.</td>
<td>LABOUR</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CHARTED BY: B.C.</td>
<td>MATERIAL</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>DATE: 6.11.48</td>
<td>TOTAL</td>
<td>$3.24</td>
<td>$1.97</td>
<td>$1.27</td>
</tr>
<tr>
<td>APPROVED BY: T.H.</td>
<td>DATE: 7.11.48</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DESCRIPTION**

<table>
<thead>
<tr>
<th>DISTANCE (m)</th>
<th>SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>QTY.</td>
<td>REMARKS</td>
</tr>
<tr>
<td>DISTANCE (m)</td>
<td>SYMBOL</td>
</tr>
<tr>
<td>1 case</td>
<td>REMARKS</td>
</tr>
<tr>
<td>Crate lifted from truck: placed on inclined plane</td>
<td>1.2</td>
</tr>
<tr>
<td>Slid on inclined plane</td>
<td>6</td>
</tr>
<tr>
<td>Placed on hand truck</td>
<td>1</td>
</tr>
<tr>
<td>Trucked to unpacking space</td>
<td>6</td>
</tr>
<tr>
<td>Lid taken off case</td>
<td>—</td>
</tr>
<tr>
<td>Trucked to receiving bench</td>
<td>9</td>
</tr>
<tr>
<td>Await unloading</td>
<td>—</td>
</tr>
<tr>
<td>Cartons taken from case: opened and tee-pieces placed on bench; counted and inspected</td>
<td>20</td>
</tr>
<tr>
<td>to drawing</td>
<td>Inspector</td>
</tr>
<tr>
<td>Numbered and replaced in case</td>
<td>Stores labourer</td>
</tr>
<tr>
<td>Await transport labourer</td>
<td>—</td>
</tr>
<tr>
<td>Trucked to distribution point</td>
<td>9</td>
</tr>
<tr>
<td>Stored</td>
<td>—</td>
</tr>
</tbody>
</table>

**TOTAL**

<table>
<thead>
<tr>
<th>DISTANCE (m)</th>
<th>SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.2</td>
<td>55</td>
</tr>
</tbody>
</table>

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It is evident that the investigators were led to ask the same question as we asked, namely: "Why does the case have to go all round the building to reach the stores?" Having received no satisfactory answer, they decided to open a fresh door into the stores opposite the benches so that the cases could be taken in by the shortest route.

It will be seen from the summary on the flow process chart (figure 23) that the "inspections" have been reduced from two to one, the "transports" from eleven to six and the "delays" (or temporary storages) from seven to two. The distance travelled has been reduced from 56.2 m to 32.2 m.

The number of man-hours involved has been calculated by multiplying the time taken for each item of activity by the number of workers involved, e.g. "trucked to reception bench" = 5 minutes by 2 labourers = 10 man-minutes. Delays are not included as they are caused by operatives being otherwise occupied. In the improved method the inspector and stores labourer are considered to be working simultaneously on inspecting and numbering respectively and the 20 minutes therefore becomes 40 man-minutes. Labour cost is reckoned at an average of $1.70 per hour for all labour. The cost of making a new doorway is not included, since it will be spread over many other products as well.

8. THE HANDLING OF MATERIALS

Principles

A great deal of publicity was given in the decade after the Second World War to the handling of materials, especially in Europe. This was one result of the visits of many teams concerned with productivity to the United States. The subject is in fact extremely important, since handling may take up as much as 85 per cent. of the total process time.

So much emphasis has been placed on it, sometimes as a result of propaganda by manufacturers of handling equipment, who are naturally anxious to increase their sales, that it was sometimes thought of as a new technique, which it is not. Method study has always been concerned with the handling of materials, and the principles involved are only those of motion economy (see Chapter 11), originally developed for the worker at his workplace, applied to the working area as a whole. Material handling is therefore a part of method study and cannot be separated from it. To attempt to deal with it separately is likely to be expensive, since equipment may be purchased which may prove useless after method study has been applied to the task for which it has been bought. For instance, a student at one of the principal work study schools in the United Kingdom, on returning to his firm at the end of his training, was able to eliminate 8 out of 17 elevating fork trucks by the application of method study. If method study had been applied before the fork trucks had been purchased a heavy outlay of money would have been avoided, and the money saved could have been used more productively elsewhere.

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Handling adds to the cost of manufacture but adds nothing to the value of the product.

Therefore the best sort of handling is no handling. The first step in tackling a handling problem is the same step used in all method study, namely to ask: “What is done?” and if the answer is “Handling”, to ask: “Why is this handling done?” with a view to trying to eliminate all handling that cannot be shown to be unavoidable.

The study of handling problems should be carried out along orthodox method study lines, using outline and flow process charts and flow diagrams so as to ensure that the layout of the working area is as good as it can be, taking account of all the circumstances, and that movement in any plane, horizontal or vertical, is reduced to a minimum. This is especially important when the purchase of handling equipment is mooted, since a change in layout will often alter not only the quantity but also the type of equipment necessary. This will be illustrated in the example given at the end of this chapter.

There are certain precepts which it is useful to bear in mind when tackling handling problems:

1. Always try to keep materials at the height at which they are to be worked upon. Wherever anything is picked up or put down there is a possibility of saving handling.

   Never put materials on the floor, where this can be avoided. Use a pallet or platform. (There is another reason for this: in a busy shop work put on the floor tends to stay on the floor and very soon accumulates instead of moving through the processes to completion.)

2. Always keep distances over which material is handled as short as possible. (This will happen automatically if proper method study procedures are carried out.)

3. Let gravity work for you. Gravity costs a lot of money in industry; it may as well be used whenever possible. Let material roll or slide down chutes to the next work station whenever possible, instead of pushing it or carrying it.

4. Always handle in bulk over distances, e.g. wait until there is a barrow-load of castings before moving them instead of having a labourer carry each one separately.

5. Always have sufficient boxes, platforms or containers available at the workplace (at least two), so that the operative can—
   remove the piece he is to work on from one container;
   place it in another when he has finished his work.
The Flow and Handling of Materials

When the second one is full it is moved to the next operation, while the first one, now empty, takes its place. This practice can be adopted very well with wheelbarrows.

(6) **Do not try to reduce the number of labourers fetching and carrying unless this can be done without adding to the handling done by direct operators.** This is an important rule, since it governs the application of the previous ones. The only exception is when the operators can do the work while necessarily unoccupied during a machine- or process-controlled cycle.

(7) **Keep gangways clear.** It is no use investing in expensive handling equipment if it is going to be held up by obstructions.

The directly productive or skilled operator should be relieved of activities which hinder him from giving all his time to his productive work. It may even increase the productivity of an undertaking as a whole if labour is specially engaged in order to relieve productive workers of tasks such as fetching and carrying their own materials.

**Equipment**

The range of equipment available for the handling of materials is far too wide to be discussed in this book. In large firms it is common to have a specialist in material handling equipment who is able to advise departments, including the work study department, on the most suitable equipment for any given purpose. In smaller firms with a limited range of activities this is not necessary. The number of different types of equipment needed in an undertaking confining its production to a small number of products is not large, and it is the business of the work study man to make himself familiar with all the equipment likely to be useful in the type of business in which he is working. Manufacturers of handling equipment are usually glad to arrange demonstrations of their products, but the work study man, while taking advantage of these to see new types, should know enough not to be persuaded into buying unsuitable equipment and, perhaps more important, not to allow his manager to be persuaded.

A special caution: do not be led into installing power-driven conveyors without very careful study, especially if there is any thought of using them for assembly work.

Power-driven conveyors may appear to be the ideal solution to problems of both assembly and transport. Method study, however, can often find cheaper and more effective means of solving them, by rearranging layouts and modifying processes. Conveyors, in their many forms, are most valuable pieces of equipment if properly used. Putting a process on to a conveyor calls for careful study and planning. All over the world conveyors are lying discarded in corners of factories.
because the processes for which they were purchased had not been properly studied first. If they had been studied, it would have been seen that the conveyors would be unsuitable.

9. EXAMPLE OF LAYOUT AND HANDLING IN AN ENGINEERING FACTORY

**RECORD**

In this example it will be shown not only how the distance travelled by material can be very much reduced by proper analysis and the use of flow process charts and flow diagrams but also how the layout affects the choice of material handling equipment.

Figure 24 shows the original layout of an engineering factory manufacturing diesel engines. It is a process layout. The two shops with which we are concerned are the general machine shop and the light machine shop, where the machines are grouped according to type (process layout). The path of movement of the cylinder head casting (weighing 50 kg) from the casting bank outside the building through the various operations will be seen on the diagram.

The following material handling equipment is used in the course of this movement. It illustrates clearly the disadvantages of the process layout in a large shop.

The part is transported by hand truck from the casting bank to Operation 1 in the light machine shop. After the first operation the part is lifted by travelling crane to the transverse gangway and loaded on to a bogie (a light railway truck) on rails on which it is transported to the end of the bay in the general machine shop where the next operation is located. It is then again picked up by overhead travelling crane and transported to Operation 2. From this operation it is again loaded on to a hand truck and taken to Operation 3 in the next bay and then returned by hand truck to Operation 4 in the light machine shop. The part goes by travelling crane, bogie and travelling crane back to Operation 5, the final operation at the far end of the general machine shop. After completion it is taken by hand truck to the general stores to await issue to the assembly shop.

The complete operation with the distances involved as shown on the flow diagram is presented in figure 25 on a flow process chart.

**EXAMINE critically**

A glance at the flow diagram suggests immediately that the casting does too much travelling. This is confirmed by the flow process chart, which goes into greater detail and records the handling at the ends of the journeys as well as the

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1 This example is adapted from the film *Layout and Handling in Factories* (London, Central Office of Information).
**FIGURE 25. FLOW PROCESS CHART: MACHINING A CYLINDER HEAD**

*(Original Method)*

<table>
<thead>
<tr>
<th>FLOW PROCESS CHART</th>
<th>MAN/MATERIAL/EQUIPMENT</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHART No. 5</td>
<td>SHEET No. 1 OF 1</td>
<td></td>
</tr>
</tbody>
</table>

**Subject charted:**
BX 3456 cylinder head

**Activity:**
Machine complete

**Method:** Present/Proposed

**Location:** Light and general machine shops

**COST:**

<table>
<thead>
<tr>
<th>OPERATOR(S):</th>
<th>CLOCK No.</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Remarks column</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHARTED BY:</th>
<th>APPROVED BY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.W.R.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DATE:</th>
<th>DATE:</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.6.50</td>
<td></td>
</tr>
</tbody>
</table>

**Description**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>QTY.</th>
<th>DISTANCE (m)</th>
<th>TIME (min)</th>
<th>SYMBOL</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>In store at casting bank</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lifted on to hand truck</td>
<td>1</td>
<td>2</td>
<td>2 labourers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucked to boring mill (1)</td>
<td>10</td>
<td>110</td>
<td>10</td>
<td>2</td>
<td>&quot;</td>
</tr>
<tr>
<td>Unloaded to floor</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>Loaded boring mill; BORED: unloaded</td>
<td>1</td>
<td>10</td>
<td>2 labourers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picked up and carried to bogie</td>
<td>1</td>
<td>4</td>
<td>B. M. operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bogie loaded</td>
<td>1</td>
<td>2</td>
<td>2 labourers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>By bogie up transverse gangway</td>
<td>5</td>
<td>110</td>
<td>2</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>Wait for crane</td>
<td>-</td>
<td>5</td>
<td>2</td>
<td>&quot; waiting</td>
<td></td>
</tr>
<tr>
<td>Picked up and carried to radial drill (2)</td>
<td>1</td>
<td>5</td>
<td>Trav. crane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unloaded to floor</td>
<td>1</td>
<td>1</td>
<td>1 labourer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded radial drill; DRILLED: unloaded</td>
<td>1</td>
<td>16</td>
<td>R. D. operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded to hand truck</td>
<td>1</td>
<td>2</td>
<td>1 labourer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucked to milling machine (3)</td>
<td>5</td>
<td>20</td>
<td>5</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>Unloaded to floor</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>Loaded to miller; Milled: unloaded</td>
<td>1</td>
<td>12</td>
<td>M. operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded to hand truck</td>
<td>1</td>
<td>2</td>
<td>1 labourer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucked to radial drill (4)</td>
<td>5</td>
<td>80</td>
<td>7</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>Unloaded to floor</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>Loaded to radial drill; DRILLED: unloaded</td>
<td>1</td>
<td>14</td>
<td>R. D. operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wait for crane</td>
<td>-</td>
<td>10</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picked up and carried to bogie</td>
<td>1</td>
<td>4</td>
<td>Trav. crane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded to bogie</td>
<td>1</td>
<td>2</td>
<td>2 labourers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>By bogie up transverse gangway</td>
<td>5</td>
<td>100</td>
<td>2</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>Picked up and carried to drill (5)</td>
<td>1</td>
<td>1</td>
<td>Trav. crane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded to radial drill; DRILLED: unloaded</td>
<td>1</td>
<td>20</td>
<td>R. D. operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded to hand truck</td>
<td>1</td>
<td>2</td>
<td>1 labourer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucked to stores</td>
<td>5</td>
<td>130</td>
<td>15</td>
<td>1</td>
<td>&quot;</td>
</tr>
<tr>
<td>Unloaded</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stored</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Total**

| TOTAL | 550 | 170 | 22 | 2 |

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journeys themselves. The casting is handled no less than 22 times (the symbol “transport” being used for handling on and off machines, etc., as well as for journeys), for five operations and travels a total distance of 550 metres, more than half a kilometre.

Since we learn from the “remarks” column that the travelling cranes used are of 2-ton (2,000 kg) capacity and that the castings are generally transported singly, the suitability of the handling equipment comes into question. This is a typical problem of general engineering shops and foundries, which have to have cranes capable of handling the heaviest items, which may be comparatively rare. Most of their time is spent in lifting and transporting items far below their capacity which are too heavy or too awkward in shape to be handled conveniently or safely by one or two men. The use of equipment which is too heavy for the job undertaken almost always slows up the work.

Another disadvantage of using travelling cranes for this type of work is that there are usually only one or two per bay and they are often engaged elsewhere when they are wanted. It will be noted from the chart that on two occasions there were delays caused by “waiting for crane”. One result of this is that workers often get tired of waiting and may themselves lift parts which are too heavy for them, with the consequent risk of injuries and accidents.

Before considering alternative means of transport the possibility of a more compact layout must be examined. This may be done by setting out templates in the appropriate positions on the flow diagram as described in section 6 of this chapter.

Critical examination shows at once that to re-locate the machines used to machine the cylinder head casting would certainly involve moving other machines as well, since they are only five among many. Flow diagrams for the other main components would have to be drawn, as shortening the distance travelled by this item might mean lengthening that travelled by another. Since complete bays in which these machines are located are made up of machines of the same type, study of the layout suggests that it might be possible to move those on which Operations 2, 3 and 5 are performed to the end of the general machine shop closer to the transverse gangway (A) and so save more than a hundred metres of movement, but this would still leave a lot of travelling.

If it is decided to change from the present process layout to a product layout other factors have to be considered. Among these are the quantities of this part manufactured per month or per year and the machining requirements of all the other parts being processed at the same time. If it can be shown that sufficient quantities of this component are required to occupy the machines on a product line full time, or if there are a number of other components which might be processed on the same line and thus give full employment to the machines, then the expense and trouble of changing them around and placing them close together in
a single line will be justified. (See pages 113 and 115 for the advantages and disadvantages of product layout.)

Placing machines close together with the operations in sequence introduces another problem—the problem of timing. If the line is to function efficiently and each machine to be used to its full capacity each operation must be of the same duration, otherwise the line very quickly becomes unbalanced, some machines being overloaded with work piling up behind them while others have periods of idleness. This may be dealt with in two ways: by duplicating machines on which long operations are performed so as to give twice (or, if necessary, three times) the capacity for this operation, or, where it can be done conveniently, splitting up a long operation into two or more shorter ones to be done on successive machines.

*DEVELOP the improved method*

Figure 26 shows the flow process chart of the improved method, while figure 27 shows the new layout. From these it will be seen that, in the event, it was considered economically worthwhile to form a product line. This made it possible to use material handling equipment which could not have been used with the old layout and which was much simpler and less expensive. It will also be seen that the drilling operations were split up from three to six, each one being of almost the same duration as the boring and milling operations.

The casting bank has been brought in from the yard and placed near the end of the line. The castings are stored on pallets and are now lifted in bulk by a fork-lift truck and placed beside the machine for Operation 1, 9 metres away. Each operator is now provided with a power-operated jib beside his workplace with which he can lift the workpiece on and off his machine without having to wait for the travelling crane, so saving time and eliminating the risk of injury through strain.

Once the casting has undergone the first operation it travels from operation to operation on a roller table until it reaches the final one, being lifted on to the machine table in each case by the jib beside the workplace. These roller tables not only act as a means of transport from operation to operation; they also provide storage space for small stocks in between operations so that the risk of any one machine running out of work is eliminated. It will be noted that the casting does not touch the ground from the time it starts the first operation to the end of the sequence when it is placed on a pallet and taken by fork-lift truck to the stores. In the flow process chart in figure 26 it is seen that the distance travelled has been reduced from 550 to 95 metres and the number of times it is handled from 22 to 13. The two delays "waiting for the travelling crane" have been eliminated. This, however, does not tell the whole story, since the handling is now much simpler and is done in every case except at the beginning and end of the sequence of operations by the machine operator himself.
## FIGURE 26. FLOW PROCESS CHART: MACHINING A CYLINDER HEAD
(Improved Method)

### FLOW PROCESS CHART

<table>
<thead>
<tr>
<th>CHART No. 6</th>
<th>SHEET No. 1</th>
<th>OF 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject charted:</td>
<td>BX 3456 cylinder head</td>
<td></td>
</tr>
</tbody>
</table>

### ACTIVITY

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>PRESENT</th>
<th>PROPOSED</th>
<th>SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATION</td>
<td>O 5</td>
<td>8</td>
<td>(3)</td>
</tr>
<tr>
<td>TRANSPORT</td>
<td>22</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>DELAY</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INSPECTION</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>STORAGE</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

### METHOD: PRESENT/PROPOSED

| DISTANCE (m) | 550 | 94.9 | 455.1 |

### LOCATION: Light and general machine shops

#### TIME (man-h)

<table>
<thead>
<tr>
<th>OPERATOR(S):</th>
<th>CLOCK No.</th>
<th>COST</th>
<th>LABOUR</th>
<th>MATERIAL</th>
<th>See Remarks column</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHARTED BY: R.W.R.</td>
<td>DATE: 27/6/50</td>
<td></td>
<td></td>
<td></td>
<td>See text</td>
</tr>
<tr>
<td>APPROVED BY: J.L.</td>
<td>DATE: 26/6/50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DESCRIPTION

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>QTY.</th>
<th>DISTANCE (m)</th>
<th>TIME (min)</th>
<th>SYMBOL</th>
<th>REMARKS</th>
</tr>
</thead>
</table>

- **In store at costing bank**
- **By fork-lift truck to boring mill (1).**
- **Pallets deposited**
- **Lifted from pallet to mill**
- **Loaded: BORED: unloaded**
- **To radial drill (2):**
- **Lifted to drill**
- **Loaded: DRILLED: unloaded**
- **To milling machine (3):**
- **Lifted to miller**
- **Loaded: MILLED: unloaded**
- **To radial drill (4):**
- **Loaded: DRILLED: unloaded**
- **To radial drill (5):**
- **Loaded: DRILLED: unloaded**
- **To radial drill (6):**
- **Loaded: DRILLED: unloaded**
- **To radial drill (7):**
- **Loaded: DRILLED: unloaded**
- **To radial drill (8):**
- **Loaded: DRILLED: unloaded**
- **Lifted off drill to pallet**
- **By fork-lift truck to stores**
- **Stored**

### TOTAL

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>TOTAL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>DISTANCE (m)</th>
<th>550</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME (man-h)</td>
<td>2.43</td>
</tr>
</tbody>
</table>

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The Flow and Handling of Materials

It will be noted that, although the total man-hours per cylinder head have been reduced from 2.43 to 1.10—a reduction of 55 per cent.—actual time on the machines, including loading into jigs or fixtures and unloading, has only been reduced from 72 minutes to 61 minutes—a reduction of 15 per cent. Most of this can probably be accounted for by reduced handling on and off the machines, the actual machining times being approximately the same. The reduction in the total time of operation is therefore almost entirely due to the elimination of excessive movement and manual handling.

It is important to note that, had not care been taken to achieve a new and simplified layout before investing in material handling equipment, it would not have been possible to use roller tables, an inexpensive and most adaptable piece of equipment; it would have been necessary to mechanise the transport from operation to operation over the original path in order to speed it up, which would have entailed spending large sums on power trucks.

In calculating the man-hours per cylinder head the “delays” in the original method have been included, as labourers were idle while waiting for the crane. Under the improved method the times on the roller table are not included, since once the cylinder head was placed on the roller table it ran by gravity to the next work station and the operator was able to turn his attention to the next piece.

Costs have not been given as their calculation in this case was very complex and would not add to the value of the example.
CHAPTER 10

MOVEMENT OF WORKERS IN THE SHOP

1. SHOP LAYOUT AND THE MOVEMENTS 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 shops it occurs when—

- bulk material is being fed to or removed from a 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.
Movement of Workers in the Shop

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.

A 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 (see figure 28) 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, 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 it is required 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 man proceeds to follow the worker in whom he is interested as he moves from point to point in doing his job. (If the working area is a fairly small one and he can see the whole of it from one point he can watch the worker
Movement of Workers in the Shop

without moving. The studyman 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.

The form of study sheet required is very simple. A sample of the headings required is given on page 140 (figure 29). Continuation sheets need only have columns 1, 2, 3, 4 and 5.

This recording will continue for as long as the work study man thinks necessary to obtain a representative picture of the worker's movements, which may be a few hours, a day, or even longer. The studyman must be sure that he has got 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 man may only have watched the worker during a part of the complete cycle of activities when he was using only a few of his various paths of movement. Later in the cycle he may not use these at all but use others a great deal. Once the studyman is satisfied that he 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.

FIGURE 28. A STRING DIAGRAM

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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.

**FIGURE 29. SIMPLE MOVEMENT STUDY SHEET**

<table>
<thead>
<tr>
<th>CHART No. 1</th>
<th>SHEET No. 1 OF 2</th>
<th>OPERATOR(S): L.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATION:</td>
<td>Transport biscuit tiles</td>
<td>CHARTED BY: S.R.</td>
</tr>
<tr>
<td>from inspection to storage bins and</td>
<td>DATE: 14. 9. 54</td>
<td></td>
</tr>
<tr>
<td>unload into bins</td>
<td>CROSS-REFERENCE: String diagrams</td>
<td></td>
</tr>
<tr>
<td>LOCATION: Biscuit warehouse</td>
<td>1 and 2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>TIME DEP.</td>
<td>TIME ARR.</td>
<td>TIME ELAPSED</td>
</tr>
<tr>
<td>Inspection bench (I)</td>
<td>to Bin 4</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

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 the example). 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 to give a picture of the paths of movement of the operator, those which are most frequently traversed being covered with the greatest number of strings, the effect being as in figure 28.
It will be seen from the sketch that certain paths—in particular those between A and D, A and H, D and L—are traversed more frequently than the others. Since most of these points are fairly distant from one another, the diagram suggests critical examination with a view to moving the work points which they represent closer together.

It will be remembered that the thread used was measured before starting 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 them.

Examination of the diagram and the development of the new layout can now proceed on the same lines as with a flow diagram, templates being used, 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 to explaining proposed changes to management, supervisors and workers. If two diagrams, one showing the original layout and one the improved layout be made, 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 to see the results of such studies and to discover how far they have to walk. The idea of reducing one’s personal effort appeals to almost everyone!

The following example shows this technique applied to the movements of labourers storing tiles after inspection.

Example of a String Diagram: Storing Tiles after Inspection

- **RECORD**

In the operation studied in this example, “biscuit” tiles (i.e. tiles after first firing and before glazing) are unloaded from kiln trucks on to the bench, where they are inspected. After inspection they are placed on platforms according to sizes and types. The loaded platforms are taken on hand-lift trucks to the concrete bins where the tiles are stored until required for glazing. The original layout of the store is shown in figure 30 overleaf.
Movement of Workers in the Shop

FIGURE 30. STRING DIAGRAM: STORING TILES
(Original Method)
It was decided to make a study using a string diagram to find out whether the arrangement, which appeared a logical one, was in fact the one involving the least transport. Studies were made of a representative number of kiln truck loads, since the types of tiles on each truck varied somewhat, although 10 cm x 10 cm and 15 cm x 15 cm plain tiles formed by far the largest part of each load.

A form of the type shown in figure 29 was used for recording the information. Only a portion is shown, since the nature of the record is obvious. (The bin numbers are those shown in figure 30.)

It will be seen that in this case times were not recorded. It is more useful to do so when long distances are involved (such as in trucking between departments of a factory).

The string diagram was then drawn up in the manner shown (figure 30). The width of the shaded bands represents the number of threads between any given points and hence the relative amount of movement between them.

- **EXAMINE critically**

A study of the diagram shows at once that the heaviest movement is up the 10 cm x 10 cm and 15 cm x 15 cm rows of bins. The bin into which any particular load of tiles is unloaded depends on which ones are full or empty (tiles are constantly being withdrawn for glazing). Travel in the case of the 10 cm x 10 cm and 15 cm x 15 cm tiles may, therefore, be anywhere up or down the rows concerned.

It is equally obvious that the “special feature” tiles (used for decorative purposes in comparatively small numbers) are handled only rarely, and are generally placed by the inspectors on one truck and delivered to several bins at once. Deliveries of tiles other than those mentioned are fairly evenly distributed.

- **DEVELOP the new layout**

The first step in developing the new layout is to locate the bins containing the tiles most handled as near as possible to the inspection bench and those containing “special feature” tiles as far away as possible. This certainly spoils the tidy sequence and may, for a time, make tiles a little more difficult to find, but the bins, which have concrete partitions between them about 1 metre high, can carry cards with the contents marked on them. The cards can be seen from a distance, and the arrangement will soon be memorised by the workers. After a number of arrangements had been tried out the one shown in figure 31 proved to be the most economical of transport time. The distances covered were reduced from 520 m to 340 m, a saving of 35 per cent.
3. THE MAN TYPE FLOW PROCESS CHART

In table 7 in Chapter 8 five different types of process chart were listed. The outline process chart was described in Chapter 8, and the two-handed process chart will be dealt with in Chapter 11. The other three are flow process charts:

Flow process chart: Man type
Flow process chart: Material type
Flow process chart: Equipment type

Several examples of material type flow process charts have already been given (figures 13 and 15 in Chapter 8; figures 21, 23, 25 and 26 in Chapter 9). It is intended to deal now with man type flow process charts.

A man type flow process chart is a flow process chart which records what the worker does.

The same techniques which have been used to follow materials through the operations and movements which they undergo can be used to record the movements of a man. Man type flow process charts are frequently used in the study of jobs which are not highly repetitive or standardised. Service and maintenance work, laboratory procedure and much of the work of supervisors and executives can be recorded on charts of this type. Since the charts follow one individual or a group performing the same activities in sequence, the standard flow process chart forms can be used. It is usually essential to attach to the man type flow process chart a sketch showing the path of movement of the worker while carrying out the operation charted.

The charting procedure used in compiling a man type flow process chart is almost exactly the same as that used on material type flow process charts. There is one slight difference however, a useful charting convention which helps to distinguish man type charts from the other two flow process charts, and which will be found quite natural in practice.

The definition of the man type chart given above states that it records what the worker does. The definitions of the other two flow process charts, however, state that they record (material type) what happens to material, and (equipment type) how the equipment is used. The definitions thus reflect the charting practice, which is to use mainly the active voice on man type charts, and mainly the passive voice on the other two. The convention, which has been followed on all the flow...
Movement of Workers in the Shop

FIGURE 31. STRING DIAGRAM: STORING TILES
(Improved Method)
Movement of Workers in the Shop

process charts illustrated in this book, will be clear from the following examples of typical entries:

Flow Process Charts

<table>
<thead>
<tr>
<th>Man type</th>
<th>Material type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drills casting</td>
<td>Casting drilled</td>
</tr>
<tr>
<td>Carries to bench</td>
<td>Carried to bench</td>
</tr>
<tr>
<td>Picks up bolt</td>
<td>(bolt) Picked up</td>
</tr>
<tr>
<td>Inspects for finish</td>
<td>Finish inspected</td>
</tr>
</tbody>
</table>

An example of man type flow process chart applied to hospital activities is given below.

Example of a Man Type Flow Process Chart: Serving Dinners in a Hospital Ward

- RECORD

Figure 32 shows the layout of a hospital ward containing 17 beds. When dinners were served by the original method the nurse in charge of the ward fetched a large tray bearing the first course, together with the plates for the patients, from the kitchen. The food was usually contained in three dishes, two of which held vegetables and the third the main dish. The nurse placed the tray on the table marked “Serving Table” in the diagram. She set the large dishes out on the table, served one plate with meat and vegetables and carried it to bed 1. She returned to the serving table and repeated the operation for the remaining 16 beds. The paths which she followed are shown by the full lines in the diagram. When she had served all the patients with the first course she returned to the kitchen with the tray and the empty dishes, collected the dishes and plates for the second course and returned to the ward. She then repeated the complete operation, replacing the plates emptied by the patients with plates containing their portions of the second course and returning the used plates to the serving table, where she stacked them. Finally she made a tour of the ward collecting up the empty plates from the second course and carried everything on the tray back to the kitchen. (To avoid confusion on the diagram, the final collection of empty plates is not shown. In both the original and the improved method the distance covered and the time taken are the same, since it is possible for her to carry several plates at a time and move from bed to bed.) The operation has been recorded in part on the flow process chart in figure 33 but only sufficiently to demonstrate to the reader the method of recording, which it will be seen is very similar to that used for material type flow process charts, bearing in mind that it is a person and not a product that is being followed. As an exercise the reader may wish to work out the serving cycles for himself on the basis provided by the diagram. The dimensions of the ward are given. It is, of course, possible to make the man type flow process chart in much greater detail if desired.

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FIGURE 32. FLOW DIAGRAM: SERVING DINNERS IN A HOSPITAL WARD

Movement of Workers in the Shop

To kitchen 12 metres from door
### FIGURE 33. FLOW PROCESS CHART—MAN TYPE: SERVING DINNERS IN A HOSPITAL WARD

#### FLOW PROCESS CHART

<table>
<thead>
<tr>
<th>CHART No. 7</th>
<th>SHEET No. 1</th>
<th>OF 1</th>
<th>ACTIVITY</th>
<th>PRESENT</th>
<th>PROPOSED</th>
<th>SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject charted: Hospital nurse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACTIVITY:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serve dinners to 17 patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### METHOD: PRESENT/PROPOSED

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>DISTANCE (m)</th>
<th>TIME (man-h.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSFER</td>
<td>436</td>
<td>39</td>
</tr>
<tr>
<td>DELAY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STORAGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCATION:</td>
<td>Ward L</td>
<td></td>
</tr>
</tbody>
</table>

#### OPERATOR(S): Nurse A.

<table>
<thead>
<tr>
<th>COST:</th>
<th>LABOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### CHARTED BY: L.M.

<table>
<thead>
<tr>
<th>MATERIAL (Trolley)</th>
<th>TOTAL (Capital)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$24</td>
<td>$24</td>
</tr>
</tbody>
</table>

#### APPROVED BY: |

<table>
<thead>
<tr>
<th>DATE:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20.12.54</td>
<td></td>
</tr>
</tbody>
</table>

#### DESCRIPTION

**ORIGINAL METHOD**

<table>
<thead>
<tr>
<th>QTY. (plates)</th>
<th>DISTANCE (m)</th>
<th>TIME (min)</th>
<th>SYMBOL</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transports first course and plates —</td>
<td></td>
<td></td>
<td></td>
<td>Awkward load</td>
</tr>
<tr>
<td>Kitchen to serving table on tray</td>
<td>17</td>
<td>16</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Places dishes and plates on table</td>
<td>17</td>
<td>—</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Serves from three dishes to plate</td>
<td>—</td>
<td>—</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Carries plate to bed 1 and return</td>
<td>1</td>
<td>7.3</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Serves</td>
<td>—</td>
<td>—</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Carries plate to bed 2 and return</td>
<td>1</td>
<td>8</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Serves</td>
<td>—</td>
<td>—</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Service completed, places dishes on tray and returns to kitchen</td>
<td>—</td>
<td>16</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Total distance and time, first cycle</td>
<td>192</td>
<td>10.71</td>
<td>17.20</td>
<td></td>
</tr>
</tbody>
</table>

**IMPROVED METHOD**

<table>
<thead>
<tr>
<th>QTY. (plates)</th>
<th>DISTANCE (m)</th>
<th>TIME (min)</th>
<th>SYMBOL</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transports first course and plates —</td>
<td>Serving trolley</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitchen to position A — trolley</td>
<td>17</td>
<td>16</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Serves two plates</td>
<td>—</td>
<td>—</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Carries two plates to bed 1; leaves one; carries one plate from bed 1 to bed 2; returns to position A</td>
<td>2</td>
<td>1.5</td>
<td>0.6</td>
<td>25</td>
</tr>
<tr>
<td>Pushes trolley to position B</td>
<td>—</td>
<td>3.0</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Serves two plates</td>
<td>—</td>
<td>—</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Carries two plates to bed 3; leaves one; carries one plate from bed 3 to bed 4; returns to position B</td>
<td>2</td>
<td>1.5</td>
<td>0.6</td>
<td>25</td>
</tr>
<tr>
<td>Pushes trolley to position B</td>
<td>—</td>
<td>3.0</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Serves two plates</td>
<td>—</td>
<td>—</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Service completed, places dishes on tray and returns to kitchen</td>
<td>—</td>
<td>16</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Total distance and time, first cycle</td>
<td>197</td>
<td>16.98</td>
<td>18.72</td>
<td></td>
</tr>
</tbody>
</table>
EXAMINE critically

A critical examination of the flow process chart in conjunction with the diagram suggests considerable room for improvement. The first "Why?" which may suggest itself is: "Why does the nurse only serve and carry one plate at a time? How many could she carry?" The answer is almost certainly: "At least two". If she carried two plates at a time the distance she would have to walk would be almost halved. One of the first questions asked would almost certainly be: "Why is the serving table there, in the middle of the ward?" followed, after one or two other questions, by the key questions: "Why should it stand still? Why can it not move round? Why not a trolley?" This leads straight to the solution which was adopted.

DEVELOP the new method

It will be seen from the broken line in the diagram (representing the revised path of movement of the nurse when provided with a trolley) and from the flow process chart that the final solution involves the nurse in serving and carrying two plates at a time (which also saves a small amount of serving time).

The result, as will be seen from the process chart, is a reduction of over 54 per cent. in the total distance walked in serving and clearing away the dinners (the saving is 65 per cent. if the distance walked in removing the second-course plates, which is the same in both the old and the new methods, is excluded).

What is important here is not so much the reduction in cost, which is very small, as the reduction in the fatigue to the nurse due to the considerable distance which she had to walk within the ward and while carrying the loaded tray to and from the kitchen.

4. THE MULTIPLE ACTIVITY CHART

We come now to the first of the charts listed in table 7 which use a time scale—the multiple activity process 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 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 operators 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 organising teams of operatives on mass-production work; 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 operator or operators should be able to look after.

In making a chart the activities of the different operators or of the different operators and machines are recorded in terms of working time and idle time. These times may be recorded by ordinary wristwatch or by stopwatch, according to the duration of the various periods of work and idleness (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 34 above.
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*

- **RECORD**

This is an application in the field of plant maintenance and is useful in showing that method study is not confined to repetition 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 34.

- **EXAMINE critically**

It will be seen from this chart that before the top of the vessel was removed by the fitter and his mate the heaters had to be removed by the electrician and his mate. This meant that the fitters had to wait until the electricians had completed their work. Similarly, at the end of the operation the electricians 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 35.

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 men will be otherwise occupied before and after performing their sections of the job and are not, in fact, idle while the heaters

---

1 Adapted from an example in *Method Study*, a handbook issued by Imperial Chemical Industries Ltd. Work Study Department.
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 above can be constructed on any piece of paper which has 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 36, 37 and 40 show multiple activity charts drawn on printed forms.
Movement of Workers in the Shop

FIGURE 36. MULTIPLE ACTIVITY CHART—MAN AND MACHINE: FINISH MILL CASTING
(Original Method)

<table>
<thead>
<tr>
<th>PRODUCT: B. 239 Casting</th>
<th>DRAWING No. B. 239/1</th>
</tr>
</thead>
</table>

| PROCESS: Finish mill second face |

| MACHINE(S): Cincinnati No. 4 vertical miller |
| SPEED | FEED | r.p.m. | in./min |
| 80 | 15 | |

<table>
<thead>
<tr>
<th>OPERATOR: Ashraf</th>
<th>CLOCK No. 1234</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man 60%</td>
<td>Machine 40%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHARTED BY: M.N.</th>
<th>DATE: 1.1.55</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TIME (min)</th>
<th>MAN</th>
<th>MACHINE</th>
<th>TIME (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Removes finished casting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Cleans with compressed air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Gauges depth on surface plate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Breaks sharp edge with file</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cleans with compressed air</td>
<td>Idle</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Places in box</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Obtains new casting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cleans machine with compressed air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>Locates casting in fixture: starts machine and auto feed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td>Working</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>Finish mill second face</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CYCLE TIME (min)</th>
<th>PROPOSED</th>
<th>SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man 2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine 2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WORKING</td>
<td>Man 1.2</td>
<td></td>
</tr>
<tr>
<td>Machine 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IDLE</td>
<td>Man 8</td>
<td></td>
</tr>
<tr>
<td>Machine 1.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Movement of Workers in the Shop

The multiple activity chart can also be used to present a picture of the operations performed simultaneously by a man and one or more machines. The chart may be drawn in the manner shown in figure 36, 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 man 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 operator’s time or of the machine time. In particular, it offers a means of determining whether a man 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 man’s time more fully. This is an important question in those countries where manpower is more readily available than machines and other capital equipment.

Example of a Multiple Activity Chart Recording Man and Machine: Finish Mill Casting on a Vertical Miller

- RECORD

Figure 36 represents a common form of man-and-machine multiple activity chart recording the operation of a vertical milling machine finish milling one face of a cast iron casting parallel to the opposite face which is used for locating it in the fixture. This is a very simple example, typical of the sort of operation carried out every day in an engineering shop.

The heading of the chart records the usual standard information with one or two additions. The graduated scale on the edge of the chart can be made to represent any scale of time required; in this case one large division equals 0.2 of a minute. The making of the chart and noting of the operations are self-evident and should not require further explanation.

- EXAMINE critically

It will be seen from figure 36, which represents the method by which the operator was doing the job before the study was made, that the machine remains idle during nearly three-quarters of the operation cycle. This is due to the fact that the operator is carrying out all his activities with the machine stopped, but remains idle while the machine is running on an automatic feed.

Examination of the chart shows that the work carried out by the operator can be divided into two parts: that which must be done with the machine stopped, such as removing and locating the workpiece, and that which can be done while the machine is running, such as gauging. It is obviously an advantage to do as much as possible while the machine is running as this will reduce the over-all operation cycle time.

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### Movement of Workers in the Shop

**FIGURE 37. MULTIPLE ACTIVITY CHART—MAN AND MACHINE: FINISH MILL CASTING**

**New Method**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DRAWING No. B.238/1</th>
<th>CHART No. 9</th>
<th>SHEET No. 1 OF 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROCESS</strong></td>
<td>Man</td>
<td>Machine</td>
<td></td>
</tr>
<tr>
<td>Finish mill second face</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MACHINE(S)</th>
<th>SPEED</th>
<th>FEED</th>
<th>IDLE</th>
<th>WORKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cincinnati No. 4 vertical miller</td>
<td>80 r.p.m.</td>
<td>15 in./min</td>
<td>Man .8</td>
<td>Machine 1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.64</td>
</tr>
</tbody>
</table>

**OPERATOR:** Ashraf

**CLOCK No. 1234**

**CHARTED BY:**

**DATE:**

<table>
<thead>
<tr>
<th>TIME min</th>
<th>MAN</th>
<th>MACHINE</th>
<th>TIME min</th>
</tr>
</thead>
<tbody>
<tr>
<td>.2</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>.4</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>.6</td>
<td></td>
<td>6</td>
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</tbody>
</table>

**Removes finished casting**

**Cleans machine with compressed air. Locates new casting in fixture: starts machine and auto feed**

**Breaks edge of machined casting with file: cleans with compressed air**

**Gauges depth on surface plate**

**Places casting in box; picks up new casting and places by machine**

**Finish mill second face**
Movement of Workers in the Shop

- **DEVELOP the new method**

Figure 37 shows the improved method of operation. It will be seen that gauging, deburring the edges of the machined face, placing the casting in the box of finished work, picking up an unmachined casting and placing it on a work table ready to locate in the fixture are now all done while the machine is running. A slight gain in time has been made by placing the boxes with the finished work and the work to be done next to one another so that one casting can be put away at the same time as the new one is lifted from its box. The cleaning of the machined casting with compressed air has been deferred until after breaking down the sharp edges, thus saving an extra operation.

The result of this rearrangement, which has involved no capital outlay, is a saving of 0.64 of a minute on 2 minutes, a gain of 32 per cent. in the productivity of the milling machine and operator.

The next example is one of a multiple activity chart recording the activities of a team of workers and a machine.

**Example of a Multiple Activity Chart Recording the Activities of a Team of Workers and a Machine:**

*Feeding Bones to a Crusher in a Glue Factory*

This interesting example of a combined teamwork and machine chart (see figure 38) applied to the feeding of sorted bones from a storage dump to a crushing machine is the work of one of the trainees of the Productivity and Vocational Training Centre set up by the Egyptian Government with the assistance of the I.L.O.

The layout of the working area as it was originally is shown in figure 39. Raw material in the form of animal bones of all sorts was brought by the suppliers to one of the dumps labelled "Bones", 80 metres from the bone crusher. The crusher was fed by means of a small trolley running on rails.

- **RECORD**

Contract labour (women) was used to sort the bones into "soft" and "hard" types. The selected bones were carried by the women to a heap ready for loading by two men into the trolley. The loading was done by hand. These two men were idle during the time that the trolley was being pushed to the crusher, emptied into it and brought back. Two other men pushed the trolley; they were idle while it was being loaded.

The following figures relate to the activities of the loaders, trolley and crushing machine during eight cycles, which lasted 117.5 minutes.
**Movement of Workers in the Shop**

**FIGURE 38. COMBINED TEAM WORK AND MACHINE MULTIPLE ACTIVITY CHART: CRUSHING BONES (Original Method)**

<table>
<thead>
<tr>
<th>MULTIPLE ACTIVITY CHART</th>
<th>CHART No. 10</th>
<th>SHEET No. 1</th>
<th>OF 7</th>
<th>(1) MACHINE(S):</th>
<th>% UTILISATION</th>
<th>(2) LABOUR:</th>
<th>% UTILISATION</th>
</tr>
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<tr>
<td>PRODUCT/MATERIAL</td>
<td></td>
<td></td>
<td></td>
<td>(1) Crusher</td>
<td></td>
<td>Trolley</td>
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<tr>
<td>Mixed bones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>68</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>OPERATION:</td>
<td></td>
<td></td>
<td></td>
<td>(2) Loaders</td>
<td></td>
<td>2</td>
<td>47.5</td>
</tr>
<tr>
<td>Load and transport bones in trolley (250 kg load) from dump to crusher</td>
<td></td>
<td></td>
<td></td>
<td>Trolleymen 2</td>
<td></td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td>METHOD:</td>
<td></td>
<td></td>
<td></td>
<td>Crushersmen 4</td>
<td></td>
<td>* Not studied</td>
<td></td>
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<td>LOCATION:</td>
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<td></td>
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<td></td>
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<tr>
<td>CHARTED BY:</td>
<td>S. Aspiotis</td>
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<table>
<thead>
<tr>
<th>TIME</th>
<th>CRUSHER</th>
<th>TROLLEY</th>
<th>TROLLEYMEN</th>
<th>LOADERS</th>
<th>TIME</th>
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<td>9.75</td>
<td>4.0</td>
<td>7.0</td>
<td>6.0</td>
<td>10</td>
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<td>20</td>
<td>10.0</td>
<td>4.25</td>
<td>7.0</td>
<td>6.0</td>
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<td>9.5</td>
<td>7.0</td>
<td>6.0</td>
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<td>4.0</td>
<td>4.0</td>
<td>7.0</td>
<td>6.0</td>
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<tr>
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<td>14.0</td>
<td>7.0</td>
<td>6.0</td>
<td>50</td>
</tr>
<tr>
<td>60</td>
<td>3.75</td>
<td>9.75</td>
<td>7.0</td>
<td>6.0</td>
<td>60</td>
</tr>
<tr>
<td>70</td>
<td>4.0</td>
<td>14.0</td>
<td>7.0</td>
<td>6.0</td>
<td>70</td>
</tr>
<tr>
<td>80</td>
<td>Replace broken belt</td>
<td>10.0</td>
<td>14.0</td>
<td>7.0</td>
<td>80</td>
</tr>
<tr>
<td>90</td>
<td>Idle, not spilled</td>
<td>6.5</td>
<td>7.0</td>
<td>6.0</td>
<td>90</td>
</tr>
<tr>
<td>100</td>
<td>6.0</td>
<td>14.0</td>
<td>7.0</td>
<td>6.0</td>
<td>100</td>
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<tr>
<td>110</td>
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<td>6.0</td>
<td>110</td>
</tr>
<tr>
<td>120</td>
<td>3.75</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>120</td>
</tr>
</tbody>
</table>

**117.5 min**
Movement of Workers in the Shop

FIGURE 39. CRUSHING BONES: LAYOUT OF WORKING AREA
Trolley loading time ............... 7 min (2 men)
Trolley to crusher, empty and return ............... 7 min (2 men)
Trolley load ................................ 250 kg
Weight transported in 117.5 minutes ............... 8 × 250 = 2,000 kg
Crusher waiting time ......................... 37.75 min

A chart (figure 38) has been made relating the activities of the crusher, trolley, trolleymen and loaders. From this it will be seen that 10 minutes of the crusher waiting time was taken up in replacing a broken belt; however, after the belt was repaired the crusher ran continuously for 16.5 minutes instead of the usual 10 because a fresh trolley load was ready for it. If a normal 4 minutes of idleness is allowed the net idleness due to the broken belt becomes only 6 minutes.

- EXAMINE critically

A critical examination of the chart shows at once that the crusher was normally idle for 31.75 out of 111.5 minutes (37.75 out of 117.5 minutes if the 6 minutes breakdown time is included), or 28.5 per cent. of the possible working time. Each of the two groups of men (loaders and trolleymen) was idle for 50 per cent. of its available time. The first question that might arise in the mind of someone studying the diagram and chart is: “Why cannot the trolleymen load the trolley?”

The answer to this question is that if they did so they would get no rest and would have to work continuously just to keep the crusher going for the same percentage of its time as at present. There would be a saving of manpower but no improvement in the productivity of the plant. In any case, no one can work for three or four hours on end without some rest, especially when engaged on heavy work like loading and pushing the trolley, where the allowance would normally be 25 per cent. or possibly more of the total time allowed for the job (for treatment of relaxation allowances see Chapter 17). If the two trolleymen took their relaxation allowances the productivity of the crusher would be still lower.

Study of the diagram of the working area and of the information given above shows that the women working on the sorting of the bones at the dumps labelled “Bones” have to carry the sorted bones from the points where they are working to the heap of “selected bones” in order that they can be loaded into the trolley. This raises the question: “Why cannot the bone sorters load the sorted bones straight into the trolley?”

The answer is that they could if the rails were extended another 20 metres to the bone dumps.

This eliminates the loaders but still leaves the problem of the 4 minutes’ idle time of the crusher while waiting for the trolley to return with a load. The bone sorters are more numerous than the loaders and they can load the trolley more quickly; if each trolley load were reduced it would take less time to load and
Movement of Workers in the Shop

**Figure 40. Combined Team Work and Machine Multiple Activity Chart: Crushing Bones (Improved Method)**

**Chart No. 11**

**Sheet No. 1 of 3**

**Material:**
- Mixed bones

**Operation:** Load and transport bones in trolley (175 kg, 500) from dump to crusher

**Method:** Present/Proposed

**Location:** Bone yard

**Charted by:** S. Aspiutsu

**Date:** 26.11.55

**Note:** N.B. Loading now done by sorters

### Multiple Activity Chart

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Crusher</th>
<th>Trolley</th>
<th>Trolleymen</th>
<th>Sorter-Loaders</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7.0</td>
<td>6.0 min per trip</td>
<td>6.0 min work</td>
<td>1.0 min loading</td>
<td>1.0 Sorting</td>
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<td>.5</td>
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<td>14.50</td>
<td>Load not emptied</td>
<td>3.0 Waiting</td>
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<td>14.75</td>
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<td>115.3 min</td>
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</tbody>
</table>

**Note:** N.B. During delays to trolley sorting continues

**Machine(s):**
- (1) Crusher: 6.0
- (2) Trolley: 9.0

**Labour:**
- (1) Crushers: 1.0
- (2) Trolleymen: 2.0
- (2) Loaders: 2.0
- (2) Crushermen: 4.0
- (2) Sorters-Loaders: 4.0

**% Utilisation:**
- Present: 60%
- Proposed: 90%
- Gain: 30%

**Not studied:**
- Transferred 47.5

**Special Notes:**
- During delays to trolley sorting continues.
would require less effort to push. In this way it might be possible to keep up with
the cycle of the crusher. The load was therefore reduced to 175 kilogrammes. Wait-
ing time was eliminated.

- DEVELOP the improved method

The line of crosses in figure 39 shows the extension of the rails to the bone
dumps. The loaders who were eliminated were transferred to other work in the
factory. This was probably made possible by the fact that, as will be seen, the crusher
output rose substantially as a result of the change of method.

Figure 40 is the multiple activity chart showing the improved method. It
will be seen from this that the percentage running time of the crusher has con-
siderably improved.

Performance figures are now—

<table>
<thead>
<tr>
<th>Performance</th>
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</thead>
<tbody>
<tr>
<td>Trolley loading time</td>
<td>1 min</td>
</tr>
<tr>
<td>Trolley to crusher, empty and return</td>
<td>6 min</td>
</tr>
<tr>
<td>Trolley load</td>
<td>175 kg</td>
</tr>
<tr>
<td>Weight transported in 115.5 minutes</td>
<td>$15 \times 175 = 2,625$ kg</td>
</tr>
<tr>
<td>Crusher waiting time</td>
<td>6 min</td>
</tr>
</tbody>
</table>

The crusher waiting time will be seen from the chart to include 3 minutes
for clearing hard bones—an abnormal occurrence. If this time is excluded to
enable the original and improved performances to be compared, the over-all time
during which the crusher is available for action is 112.5 minutes. The increase
in output from the crusher over almost identical periods is 625 kilogrammes; the
increase in productivity of the crusher is 29.5 per cent.

Two labourers out of eight have been released for other work; the labour
productivity has therefore increased by

$$\left( \frac{2625 \times 8}{2000 \times 6} - 1 \right) \times 100 = 75 \text{ per cent}.$$ 

The annual saving in labour cost was £E.500.

The space formerly occupied by the “selected bones” is now available for
other uses.

This example is a dramatic illustration of the manner in which the produc-
tivity of land, plant and labour can be increased by method study properly and
systematically applied, at a cost of only an additional 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 shop, especially when readily understood “before” and “after” models are required 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 to use.

*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 41 shows a typical travel chart recording the movements of a messenger delivering papers or information to the various desks and work stations in an office. The layout of the office, showing the relative positions of the work stations, is sketched beneath the travel chart.

The travel chart is always a square, having within it smaller squares. Each small square represents a work station—that is, a place visited by the messenger, in the present example. 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 when all is complete, for ten work stations 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 studyman enters the travel chart at the square numbered 2 along the top of the chart, runs his pencil down vertically through all the squares underneath this one until he reaches that square which is horizontally opposite the station marked 9 on the left-hand edge. This is the terminal square, and he 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, all travelling vertically downwards, and all ending in the square opposite the station of arrival, as read from the left-hand edge. Of course, the studyman does not actually trace in the path over which his pencil moves but just places a small tick or other mark in the terminal square to record the journey.
FIGURE 41. TRAVEL CHART: MOVEMENTS OF MESSENGER IN OFFICE

Movement FROM

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Summary of movements INTO station number

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Layout sketch of office showing location of stations
To make the recording method completely clear, let us suppose that the messenger travelled the 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 that from 9 to 5, the studyman will return to the top of the chart, select square 9, move down the column below this until he 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 Travel Chart: Movement of Messenger in an Office

- **RECORD**

  The first stage of the recording process, that when the method study man 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 42. 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.

  In the method study office, the travel chart is then compiled. 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 summarised, 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 41 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 10 movements shown, into station 2. For the movements from stations, the totalling is carried out vertically: it will be seen that there were 10 movements into 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 41 the summary of movements into each station shows the same number of movements as are recorded at the bottom as being made from that station, indicating that the messenger wound up at the end of his travels at the same station as he started out from when the study commenced. If he had finished somewhere else (or if the study had been broken off when he 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

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. 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 will be better to locate these stations next to each other. It may 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 work on to station 9, thus relieving the messenger of a good deal of his travelling.
Movement of Workers in the Shop

Example of a Travel Chart: Materials Handling

An example of a travel chart compiled as part of a materials handling study is shown in figure 43. In the shop in which the study was made, eight mixing machines were used to mix materials in different proportions, the final mixtures being taken to an inspection bench, station 6. The mixes were transported in 25-litre cans, which were placed on pallets and moved by a low lift truck.

- RECORD

Movements were recorded on the shop floor on a study sheet of the type shown in figure 42. The entries show not only the journeys made but also the number of cans carried on each trip. The travel chart constructed from this infor-
Movement of Workers in the Shop

...mation is shown in figure 43. There are nine stations, the eight mixing machines and
the inspection bench. The travel chart was made exactly as in the previous example
except that in this instance the number of cans delivered was also entered in the
destination squares, alongside the ticks for the journeys, and both journeys and
cans delivered have been summarised. It will be seen that, for instance, two journeys
were made from station 5 to station 9, one with a load of 40 cans and the other
with 30.

• **EXAMINE critically**

  Not much can be learned from the study sheet, except that of the 29 trips
made seven were run without any load, and that the size of load varied from 10 to 40
cans. The travel chart, however, shows at once that stations 6 and 9 are busy ones.
Five trips were made to station 6, delivering a total of 150 cans. (Station 6 was the
inspection bench.) Four of these trips were from station 9, bringing in a total of
130 cans. The largest number of trips, and the greatest quantity of cans, was from
station 9 to the inspection bench, suggesting that this route might be laid out so as
to be as short as possible. It may be possible to install a roller conveyor between
these points, thus relieving the lift truck of a great deal of work.

  Eight trips were made into station 9, to deliver 170 cans. The cans came from
stations 1, 2, 4 and 5, one trip without load being made from station 3. Stations 1,
2, 4 and 5 appear to feed station 9, which sends its work on to the inspection bench
(longer study might be necessary to confirm this). If so, there will be a case for
re-laying out the shop to bring these stations closer together, when roller conveyors
might allow gravity to do most of the transporting between them. In this example
there is no sketch of the shop layout or table of distances between stations, both of
which are essential complements to a travel chart.

  It is interesting to note that four trips were made from station 2, but only
three into the station; and that four only were made from station 6 although five
were made into it. This is because the study started at station 2 and finished at the
inspection bench.
CHAPTER 11

METHODS AND MOVEMENTS AT THE WORKPLACE

1. GENERAL

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 men 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 material to men, we have discussed methods of studying the movements of men around the working area and the relationships between men and machines or of men working together in groups. We have done so following the principle that the broad method of operation must be put right before attempting improvements in detail.
Movements at the Workplace

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

In considering the movements of men and materials on the larger scale we have been concerned with the better utilisation of existing plant and machinery (and, where possible, materials) through the elimination of unnecessary idle time, the more effective operation of processes and the better utilisation 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 of the Egyptian trolleymen’s need for relaxation shows, the factor of fatigue affects the solution of problems even when dealing with areas larger than the individual workplace. But when we come to study the operator at the workplace, the way in which he applies his effort and the amount of fatigue resulting from his manner of working become primary factors in affecting his productivity.

Before embarking on a detailed study of an operator 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 to

- **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 operator at his workplace in ways which facilitate critical examination and the development of improved methods, in particular the **two-handed process chart**. 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 task.

### 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 were first used by Frank Gilbreth, the founder of motion study, and have been amplified by other workers, notably Professor Barnes. 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 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.**

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).**

---

1. In the *British Standards Glossary of Terms in Work Study* the term *characteristics of easy movement* is preferred, rather than “the principles of motion economy”. The earlier term has been retained here, however, as being more descriptive of the rest of this section of the chapter.

Movements at the Workplace

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.

B. Arrangement of the Workplace

1. Definite and fixed stations should be provided for all tools and materials to permit habit formation.

2. Tools and materials should be pre-positioned to reduce searching.

3. Gravity feed, bins and containers should be used to deliver the materials as close to the point of use as possible.

4. Tools, materials and controls should be located within the maximum working area (see figure 44) and as near to the worker as possible.

5. Materials and tools should be arranged to permit the best sequence of motions.

6. "Drop deliveries" or ejectors should be used wherever possible so that the operator does not have to use his hands to dispose of the finished work.

7. Provision should be made for adequate lighting, and a chair of the type and height to permit good posture should be provided. The height of the workplace and seat should be arranged to allow alternate standing and sitting.

8. The colour of the workplace should contrast with that of the work and thus reduce eye fatigue.

C. Design of Tools and Equipment

1. The hands should be relieved of all work of "holding" the workpiece where this can be done by a jig, fixture or foot-operated device.

2. Two or more tools should be combined wherever possible.
3. Where each finger performs some specific movement, as in typing, the load should be distributed in accordance with the inherent capacities of the fingers.

4. Handles such as those on cranks and large screwdrivers should be designed so as to permit as much of the surface of the hand as possible...
to come into contact with the handle. This is especially necessary when considerable force has to be used on the handle.

5. Levers, crossbars and handwheels should be so placed that the operator can use them with the least change in body position and the greatest "mechanical advantage".

These “principles” can be made the basis of a summary “questionnaire” which will help, when laying out a workplace, to ensure that nothing is overlooked.

Figure 44 shows the normal working area and the storage area on the workbench for the average operative. As far as possible materials should not be stored in the area directly in front of him, as stretching forwards involves fatiguing use of the back muscles. This has been demonstrated by physiological research.

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.

<table>
<thead>
<tr>
<th>Class</th>
<th>Pivot</th>
<th>Body member(s) moved</th>
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<tbody>
<tr>
<td>1</td>
<td>Knuckle</td>
<td>Finger</td>
</tr>
<tr>
<td>2</td>
<td>Wrist</td>
<td>Hand and fingers</td>
</tr>
<tr>
<td>3</td>
<td>Elbow</td>
<td>Forearm, hand and fingers</td>
</tr>
<tr>
<td>4</td>
<td>Shoulder</td>
<td>Upper arm, forearm, hand and fingers</td>
</tr>
<tr>
<td>5</td>
<td>Trunk</td>
<td>Torso, upper arm, forearm, hand and fingers</td>
</tr>
</tbody>
</table>

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. In laying out the workplace, placing everything required within easy reach will minimise the class of movement which the work itself exacts from the operator.

4. FURTHER NOTES ON WORKPLACE LAYOUT

A few general notes on laying out the workplace may be useful.

1. If similar work is being done by each hand there should be a separate supply of materials or parts for each hand.
2. If the eyes are used to select material the latter should be kept as far as possible in an area where the eyes can locate them without turning the head.

3. The nature and the shape of the material influence its position in the layout.

4. Hand tools should be picked up with the least possible disturbance to the rhythm and symmetry of movements. As far as possible the operator should be able to pick up or put down a tool as the hand moves from one part of the work to the next, without making a special journey. Natural movements are curved, not straight; tools should be placed on the arc of movements, but clear of the path of movement of any material which has to be slid along the surface of the bench.

5. Tools should be easy to pick up and replace; as far as possible they should have an automatic return, or the location of the next piece of material to be moved should allow the tool to be returned as the hand travels to pick it up.

6. Finished work should be—
   (a) dropped down a hole or a chute;
   (b) dropped through a chute when the hand is starting the first motion of the next cycle;
   (c) put in a container placed so that hand movements are kept to a minimum;
   (d) if the operation is an intermediate one, placed in a container in such a way that the next operator can pick it up easily.

7. Always look into the possibility of using pedals or knee-operated levers for locking or indexing devices on fixtures or devices for disposing of finished work.

An Example of a Workplace Layout

Let us now look at a typical workplace with the principles of motion economy and the notes in the previous section in mind.

Figure 45 shows a typical example of the layout of a workplace for the assembly of small electrical equipment (in this case electric meters) developed by one of the trainees of the Israel Institute of Productivity. Certain points will be noticed at once:

(a) A fixture has been provided for holding the workpiece (here the chassis of the meter), leaving both the operator's hands free to use for assembly. The use of one hand purely for holding the part being
worked on should always be avoided except for operations so short that a fixture would not be justified.

(b) The power screwdriver and box spanner are suspended in front of the operator so that she only has to make a very short and easy movement to grasp them and bring them to the work. They are, however, clear of the surface of the table and of the work. The hammer and hand screwdriver for use of the left hand are within easy reach so that the operator can pick them up without searching, although picking up the screwdriver might necessitate a little fumbling. They are in line with the trays of parts but below them and do not get in the way.

(c) All the small parts are located close to the operator, well within the “maximum working area”. Each part has a definite location and the trays are designed with “scoop” fronts for easy withdrawal, parts
being drawn forward with the tips of the fingers and grasped as they come over the rounded edge. They are arranged for symmetrical movements of the arms so that parts which are assembled simultaneously are picked up from trays in the same relative position to the operator on either side of her. It will be noted that the trays come almost in front of the operator, but this is not very important in this case as the length of reach is not excessive and will not involve much play of the shoulder and back muscles.

\[(d)\] The operator has taken a small number of the formed wire parts normally kept in a tray to her left front and placed them conveniently in front of and to the side of the workpiece to make a shorter reach.

\[(e)\] The backrest of the operator's chair is an interesting and ingenious improvisation. Special chairs with this type of backrest were not produced locally.

5. NOTES ON THE DESIGN OF JIGS, TOOLS AND FIXTURES

<table>
<thead>
<tr>
<th>A jig holds parts in an exact position and guides the tool that works on them.</th>
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<table>
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<tr>
<th>A fixture is a less accurate device for holding parts which would otherwise have to be held in one hand while the other worked on them.</th>
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The designer's object in providing jigs and fixtures is primarily accuracy in machining or assembly. Often opening and closing them or positioning the workpiece calls for more movements on the part of the operator than are strictly necessary. For example, a spanner may have to be used to tighten a nut when a wing nut would be more suitable; or the top of the jig may have to be lifted off when the part might be slid in.

Co-operation between the work study man and the jig and tool designers, in industries where they are employed (principally the engineering industry), should start in the early stages of designing, and tool designers should be among the first people to take appreciation courses in method study. Some points worth noting are—

\[(a)\] Clamps should be as simple to operate as possible and should not have to be screwed unless this is essential for accuracy of positioning. If two clamps are required they should be designed for use by the right and left hands at the same time.
Movements at the Workplace

(b) The design of the jig should be such that both hands can load parts into it with a minimum of obstruction. There should be no obstruction between the point of entry and the point from which the material is obtained.

(c) The action of unclamping a jig should at the same time eject the part, so that additional movements are not required to take the part out of the jig.

(d) Where possible on small assembly work, fixtures for a part which does not require both hands to work on it at once should be made to take two parts, with sufficient space between them to allow both hands to work easily.

(e) In some cases jigs are made to take several small parts. It will save loading time if several parts can be clamped in position as quickly as one.

(f) The work study man should not ignore machine jigs and fixtures such as milling jigs. A great deal of time and power is often wasted on milling machines owing to the fact that parts are milled one at a time when it may be quite feasible to mill two or more at once.

(g) If spring-loaded disappearing pins are used to position components, attention should be given to their strength of construction. Unless the design is robust such devices tend to function well for a while but then have to be repaired or redesigned.

(h) In introducing a component into a jig it is important to ensure that the operator should be able to see what he is doing at all stages; this should be checked before any design is accepted.

6. MACHINE CONTROLS AND DISPLAYS OF DIALS

Machinery and plant of all kinds was until recently designed with very little consideration for the convenience of the operator. In short cycle work especially, the manipulation of the controls (changing speeds on a capstan lathe, for example) often involves awkward movements. Textile machinery has been a particularly bad offender in this respect, and much of it still requires fatiguing effort and movement on the part of the operator. There is not much that the user can do about the controls of a machine once he has bought it, but he can draw the attention of the makers to inconvenient controls so that they can make improvements in later models. There is evidence that machinery makers generally are beginning to apply method study to their products, but a great deal remains to be done. In the few companies that make their own machinery or plant the work study department should be called in at the earliest possible stage of the designing.
Attention has been given by physiologists and psychologists to the arrangement of dials with a view to minimising the fatigue of people who have to watch them. Arrangements of the control panels for chemical processes and similar types of process are often made at the works installing them, and the work study man should be consulted when this is done.

There is a good deal of published literature on the subject which can be consulted with a view to obtaining an easily readable “display” or arrangement of dials or visual indicators.

The growing awareness of the importance of arranging machine controls and workplaces so that they are convenient for the people who have to do the work has led in recent years to the development of a new field of scientific study which is concerned entirely with such matters. This is ergonomics: the study of the relation of a worker and the environment in which he works, particularly the application of anatomical, physiological and psychological knowledge to the problems arising therefrom. Ergonomists have carried out many experiments to determine such things as the best layout for machine controls, the best dimensions for seats and worktops, the most convenient pedal pressures and so on. It may be expected that their findings will be increasingly incorporated in the designs of new machines and equipment over the next few years, and will eventually form the basis of standard practice.

7. THE TWO-HANDED PROCESS CHART

Study of the work of an operator at the bench starts, as does method study over the wider field, with a process chart. In this case it is the fifth of the charts indicating process sequence (table 7), that known as the two-handed process chart.

The two-handed process chart is a process chart in which the activities of a worker’s hands (or limbs) are recorded in their relationship to one another.

The two-handed process chart is a specialised form of process chart because it shows the two hands (and sometimes the feet) of the operator moving or static in relation to one another, usually in relation to a time scale. One advantage of a time scale on the chart form is that it brings the symbols for what the two hands are doing at any given moment opposite to one another.

The two-handed process chart is generally used for repetitive operations, when one complete cycle of the work will be recorded. Recording is carried out in more detail than is normally used on flow process charts. What may be shown as a single operation on a flow process chart may be broken down into a number of elemental activities which together make up the operation. The two-handed process
Movements at the Workplace

chart generally employs the same symbols as the other process charts but because of the greater detail covered the symbols are accorded slightly different meanings—

**OPERATION** is used for the activities of grasp, position, use, release, etc. of a tool, component or material.

**TRANSPORT** is used to represent the movement of the hand (or limb) to or from the work, or a tool, or material.

**DELAY** is used to denote time during which the hand or limb being charted is idle (although the others may be in use).

**HOLD** ("Storage") The term *storage* is not used in connection with the two-handed process chart. Instead, the symbol is re-designated as *hold* and is used to represent the activity of holding work, tool or material—that is, when the hand being charted is holding something.

The symbol for *inspection* is not much used because the hand movements when inspecting an article (holding it and examining it visually or gauging it) may be classified as "operations" on the two-handed chart. It may, however, sometimes be useful to employ the "inspection" symbol to draw attention to the examination of a piece.¹

The very act of making the chart enables the work study man to gain an intimate knowledge of the details of the job, and the chart itself enables him to study each element of the job by itself and in its relation to other elements. From this study ideas for improvements are developed. These ideas should be written down in chart form when they occur, just as in all other process charting. It may be that different ways of simplifying the work can be found; if they are all charted they can be compared easily. The best method is generally that which requires the fewest movements.

The two-handed process chart can be applied to a great variety of assembly, machining and clerical jobs. In assembly operations tight fits and awkward positioning present certain problems. In the assembly of small parts with close fits "positioning before assembly" may be the longest element in the cycle. In such cases "positioning" should be shown as a separate movement ("Operation") apart from the actual movement of assembly (e.g. fitting a screwdriver in the head of a small screw). This enables attention to be focused on it and, if it is shown against a time scale, its relative importance can be assessed. Major savings can be made if

¹ Some authorities feel that the standard process-chart symbols are not entirely suitable for recording hand and body movements and have adopted variants. In Sweden the following breakdown of activities is used:

- **O**: Operation
- **H**: Hold
- **TL**: Transport Loaded
- **R**: Rest
- **TE**: Transport Empty

the number of such positionings can be reduced, as for example by slightly countersinking the mouth of a hole and putting a chamfer on the end of the shaft fitting in it, or by using a screwdriver with a self-centring bit.

**Notes on Compiling Two-Handed Process Charts**

The chart form should include—

Spaces at the top for the usual information.

Adequate space for a sketch of the layout of the workplace (corresponding to the flow diagram used in association with the flow process chart), or sketch of jigs, etc.

Spaces for the movements of right and left hands.

Space for a summary of movements and analysis of idle time.

Examples are given in the following pages.

Some points in compiling charts are worth mentioning—

1. Study the operation cycle a few times before starting to record.
2. Chart one hand at a time.
3. Do not record more than a few symbols at a time.
4. Picking up or grasping a fresh part at the beginning of a cycle of work is a good point to start the record. Start with the hand that handles the part first or the hand that does the most work. The exact point of starting is not really important, as the complete cycle will eventually come round to it again, but the point chosen must be definite. Add in the second column the kinds of work done by the other hand.
5. Only record actions on the same level when they occur at the same moment.
6. Actions which occur in sequence must be recorded on the chart at different horizontal levels. Check the chart for the time relation of the hands.
7. Care must be taken to list everything the operator does and to avoid combining operations and transports or positionings, unless they actually occur at the same time.

**Example of a Two-Handed Process Chart: Cutting Glass Tubes**

This very simple example is one taken from the work done by a trainee of the first I.L.O. productivity mission to India. The nature of the job (cutting off short
Movements at the Workplace

FIGURE 46. TWO-HANDED PROCESS CHART: CUTTING GLASS TUBES
(Original Method)

TWO-HANDED PROCESS CHART

CHART No. 1 SHEET No. 1 OF 1

DRAWING AND PART: Glass tube 3 mm dia.,
1 metre original length

OPERATION: Cut to lengths of 1.5 cm

LOCATION: General shop

OPERATOR: D.G.

CHARTED BY: A.B. DATE: 22.7.52

Holds tube
To jig
Inserts tube to jig
Presses to end
Holds tube
Withdraws tube slightly
Rotates tube 120°/180°
Pushes to end jig
Holds tube
Withdraws tube
Moves tube to R.H.
Bends tube to break
Holds tube
Changes grasp on tube
Picks up file
Holds file
File to tube
Holds file
Notches tube with file
Holds file
Holds file
Moves file to tube
Notches tube
Places file on table
Moves to tube
Bends tube
Releases cut piece
To file

SUMMARY

<table>
<thead>
<tr>
<th>METHOD</th>
<th>PRESENT</th>
<th>PROPOSED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L.H.</td>
<td>R.H.</td>
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<td>Operations</td>
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</tr>
<tr>
<td>Transports</td>
<td>2</td>
<td>5</td>
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<td>–</td>
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<td>Holds</td>
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<tr>
<td>Inspections</td>
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<td>–</td>
</tr>
<tr>
<td>Totals</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

182
lengths of glass tube with the aid of a jig) is explained on the form; the operations involved are self-explanatory (figure 46).

- **RECORD**

In the original method the tube was pressed to the stop at the end of the jig, marked with the file and then eased back for notching. It was then taken out of the jig for breaking. The chart goes into much detail in recording the movements of the hands because in short cycle work of this kind fractions of seconds, when added together, may represent a large proportion of the total time needed for the job.

- **EXAMINE critically**

An examination of the details of the original method using the questioning technique at once raises certain points. (It is not considered necessary to go through the questions in sequence at this stage in the book: it is assumed that the reader will always do so.)

1. Why is it necessary to hold the tube in the jig?
2. Why cannot the tube be notched while it is being rotated instead of the right hand having to wait?
3. Why does the tube have to be taken out of the jig to break it?
4. Why pick up and put down the file at the end of each cycle? Can it not be held?

A study of the sketch will make the answers to the first three questions plain.

1. The tube will always have to be held because the length supported by the jig is short compared with the total length of the tube.
2. There is no reason why the tube cannot be rotated and notched at the same time.
3. The tube has to be taken out of the jig to be broken because, if the tube were broken by bending against the face of the jig, the short end would then have to be picked out—an awkward operation if very little were sticking out. If a jig were so designed that the short end would fall out when broken it would not then be necessary to withdraw the tube.

The answer to the fourth question is also obvious.

4. Both hands are necessary to break the tube using the old method. This might not be necessary if a new jig could be devised.
Movements at the Workplace

**FIGURE 47. TWO-HANDED PROCESS CHART: CUTTING GLASS TUBES**  
(Improved Method)

<table>
<thead>
<tr>
<th>TWO-HANDED PROCESS CHART</th>
<th>WORKPLACE LAYOUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHART No. 2 SHEET No. 1 OF 1</td>
<td>WORKPLACE LAYOUT</td>
</tr>
<tr>
<td>DRAWING AND PART: Glass tube 3 mm dia. 1 metre original length</td>
<td>WORKPLACE LAYOUT</td>
</tr>
<tr>
<td>OPERATION: Cut to lengths of 1.5 cm</td>
<td>WORKPLACE LAYOUT</td>
</tr>
<tr>
<td>LOCATION: General shop</td>
<td>IMPROVED METHOD</td>
</tr>
<tr>
<td>OPERATOR: D.G.</td>
<td>GLASS TUBE</td>
</tr>
<tr>
<td>CHARTED BY: A.B. DATE: 23.7.52.</td>
<td>POSITION FOR NOTCH</td>
</tr>
<tr>
<td>LEFT-HAND DESCRIPTION</td>
<td>RIGHT-HAND DESCRIPTION</td>
</tr>
<tr>
<td>Pushes tube to stop</td>
<td>Holds file</td>
</tr>
<tr>
<td>Rotates tube</td>
<td>Notches with file</td>
</tr>
<tr>
<td>Holds tube</td>
<td>Taps with file:</td>
</tr>
<tr>
<td>end drops to box</td>
<td></td>
</tr>
</tbody>
</table>

**SUMMARY**

<table>
<thead>
<tr>
<th>METHOD</th>
<th>PRESENT</th>
<th>PROPOSED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>L.H.</td>
<td>R.H.</td>
</tr>
<tr>
<td>Operations</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Transports</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Delays</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Holds</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Inspections</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Totals</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>
Movements at the Workplace

- DEVELOP the new method

Once these questions have been asked and answered, it is fairly easy to find a satisfactory solution to the problem. The solution found by the trainee is to be seen in figure 47. It will be seen that, in redesigning the jig, he has arranged it in such a way that the notch is cut on the right-hand side of the supporting pieces, so that the short end will break away when given a sharp tap and it will no longer be necessary to withdraw the tube and use both hands to break off the end. The new method is described in the process chart in that figure.

The number of operations and movements has been reduced from 28 to six, as a result of which an increase in productivity of 133 per cent. was expected. In actual fact this was exceeded because the job is now more satisfactory owing to the elimination of irritating work such as “position tube in jig”. The new method can be carried out without looking closely at the work, so that workers can be trained more easily and become less fatigued.

8. REORGANISATION OF A WORKPLACE BY MEANS OF A TWO-HANDED PROCESS CHART

Assembly of Power Motor Starting Winding to Core

Figure 48 shows the workplace before reorganisation. Some thought has evidently been given to the operation, since a fixture has been provided for holding the assembly. Apart from this, the organisation of the workplace appears to have been left to the worker. The various tools and the ring gauge are placed quite conveniently at her right hand, although a study of the “Before” process chart shows that she always has to pick up the tamping tools with her right hand and pass them to her left. This occurs seven times in the course of one assembly. The handles of the tools are awkward to grasp since they lie flat on the bench. Lengths of systoflex tubing are upright in a tin in front of the fixture (a long reach for the worker). The prepared coils (not visible in this figure but seen in a tray in figure 49) are stated in the process chart to be placed on the shelf in front of the worker (another long reach).

Figure 50 shows the two-handed process charts before and after the alteration in method and re-layout of the workplace, in the original form in which they were drawn at the time. The process charts are accompanied (figure 51) by right- and left-handed activity charts (not described in this book) which show the relative activity of the individual hands. From these it will be seen that under the original

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1 This example from industrial practice was provided by the General Electric Company Ltd., Witton, England, through whose courtesy the photographs and process charts have been made available. The process charts are reproduced in their original form. It will be seen that they differ somewhat from the newer practice recommended in this book, but careful examination will make them perfectly clear to the reader.
FIGURE 48. EXAMPLE OF WORKPLACE LAYOUT
(Original Method)
FIGURE 49. EXAMPLE OF WORKPLACE LAYOUT
(New Method)
method the left hand is idle during a considerable part of the cycle: the right hand performs nearly twice as many operations. Reference to the "Before" process chart shows that the left hand is used very largely either to hold components or to assist the right hand.

The "After" activity chart shows that the activities of the two hands are more nearly balanced. The number of operations performed by the right hand has been reduced to 143, although the number of delays has increased from nine to 16. This, however, is more than compensated by the reduction in both the number and duration of the delays of the left hand, whose operations have been reduced to 129. It will be seen also in figure 50 that transport by hand (H) has been eliminated by the use of a conveyor (C).

The "After" process chart shows that the left hand is now much more usefully employed. There is only one "hold" for each hand; although the left hand is still used to some extent to assist the right it is also used to carry out a number of operations of its own.

The process chart, although it gives details of the change in method, does not give any indication of the change in the workplace layout. This may be seen in figure 49.

The workplace has been laid out according to the principles of motion economy and the working areas shown in figure 44. The workpiece and all the components and tools are well within the maximum working area. The fixture is the same, but it has been placed nearer the edge of the bench, where it is more convenient to the worker. The systoflex, wedges and other components are conveniently located in standard trays; the coils (a larger item) are in the large tray within easy reach of the worker's left hand. Special note should be taken of the positioning of the tools. These are located for the use of the appropriate hand with the handles in a position easy to grasp: even the scissors are tucked between the trays with their handles upwards. The ring gauge which in figure 48 is to be seen lying flat on the bench, a difficult position from which to pick it up, is now upright in a specially shaped tin on the right-hand side of the bench where it is very simple to grasp: the operative need not look up from her work.

Figure 49 repays careful study. The compactness of the workplace encourages the operative to keep things in their proper places: a large amount of bench space is an invitation to scatter tools and components on it. From the point of view of economy of factory space this new layout will pay for itself in two ways: first, by making possible more workplaces in a given area, and secondly, by providing greater output from a given workplace. The operative will also find the work much less tiring through not having to stretch and search.
FIGURE 51. RIGHT- AND LEFT-HANDED ACTIVITY CHARTS: ASSEMBLY OF
POWER MOTOR STARTING WINDING TO CORE

<table>
<thead>
<tr>
<th>OBJECT No.</th>
<th>LEFT HAND ACTIVITY</th>
<th>RIGHT HAND ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BEFORE</td>
<td>AFTER</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td>3</td>
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<td></td>
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<td>29</td>
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<tr>
<td>30</td>
<td></td>
<td></td>
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<tr>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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9. MICROMOTION STUDY

In certain types of operation, and particularly those with very short cycles which are repeated thousands of times (such as the packing of sweets into boxes or food cans into cartons), it is worth while going into much greater detail to determine where movements and effort can be saved and to develop the best possible pattern of movement, thus enabling the operator to perform the operation repeatedly with a minimum of effort and fatigue. The techniques used for this

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Abbreviation</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search</td>
<td>Sh</td>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>Find</td>
<td>F</td>
<td>Grey</td>
<td></td>
</tr>
<tr>
<td>Select</td>
<td>St</td>
<td>Light Grey</td>
<td></td>
</tr>
<tr>
<td>Grasp</td>
<td>G</td>
<td>Red</td>
<td></td>
</tr>
<tr>
<td>Hold</td>
<td>H</td>
<td>Gold ochre</td>
<td></td>
</tr>
<tr>
<td>Transport Load</td>
<td>TL</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>P</td>
<td>Blue</td>
<td></td>
</tr>
<tr>
<td>Assemble</td>
<td>A</td>
<td>Violet</td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td>U</td>
<td>Purple</td>
<td></td>
</tr>
<tr>
<td>Disassemble</td>
<td>DA</td>
<td>Light violet</td>
<td></td>
</tr>
<tr>
<td>Inspect</td>
<td>I</td>
<td>Burnt ochre</td>
<td></td>
</tr>
<tr>
<td>Pre-position</td>
<td>PP</td>
<td>Pale blue</td>
<td></td>
</tr>
<tr>
<td>Release load</td>
<td>RL</td>
<td>Carmine red</td>
<td></td>
</tr>
<tr>
<td>Transport Empty</td>
<td>TE</td>
<td>Olive green</td>
<td></td>
</tr>
<tr>
<td>Rest for overcoming fatigue</td>
<td>R</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>Unavoidable delay</td>
<td>UD</td>
<td>Yellow</td>
<td></td>
</tr>
<tr>
<td>Avoidable delay</td>
<td>AD</td>
<td>Lemon yellow</td>
<td></td>
</tr>
<tr>
<td>Plan</td>
<td>Pn</td>
<td>Brown</td>
<td></td>
</tr>
</tbody>
</table>
purpose frequently make use of filming, and are known collectively as micromotion study.

The micromotion group of techniques is based on the idea of dividing human activity into divisions of movements or groups of movements (known as “therbligs”) according to the purpose for which they are made.

These were devised by Frank B. Gilbreth, the founder of motion study; the word “therblig” is an anagram on his name. Gilbreth differentiated 17 fundamental hand or hand and eye motions, to which an eighteenth has subsequently been added. The therbligs cover movements or reasons for the absence of movement. Each therblig has a specific colour, symbol and letter for recording purposes. These are shown in table 9.

Therbligs refer primarily to motions of the human body at the workplace and to the mental activities associated with them. They permit a much more precise and detailed description of the work than any other method so far described in this book. On the other hand, considerable practice is required in their identification before they can be used for analysis with any degree of assurance.

It is not felt necessary in an introductory book of this kind to go deeply into these techniques because so much can be done in the improvement of productivity using the simpler ones already described before it becomes necessary to use such refinements. They are used much less than the simpler techniques, even in the highly industrialised countries, and then mainly in connection with mass-production operations, and they are more preached about than practised. There are a number of good textbooks dealing with them in detail, some of which are mentioned in the book list. They are, however, techniques for the expert, and in any case it would be foolish for the trainee or comparatively inexperienced work study man to waste his time trying to save split seconds when there are sure to be plenty of jobs whose productivity can be doubled and even trebled by using the more general methods. Keep off the advanced work until the big savings have been made using the broad techniques.

10. THE SIMO CHART

Only one recording technique of micromotion study will be described here briefly, namely the simultaneous motion cycle chart, known as the simo chart for short.

A simo chart is a chart, often based on film analysis, used to record simultaneously on a common time scale the therbligs or groups of therbligs performed by different parts of the body of one or more workers.
Movements at the Workplace

FIGURE 52. A SIMO CHART

<table>
<thead>
<tr>
<th>DRAWING No. AND NAME</th>
<th>27 Bottle Dropper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td></td>
</tr>
<tr>
<td>OPERATION</td>
<td>Assemble</td>
</tr>
<tr>
<td>OP. No.</td>
<td>DT 27 A</td>
</tr>
<tr>
<td>OPERATOR</td>
<td>L. Jones — 345</td>
</tr>
<tr>
<td>FILM No.</td>
<td>A — 6 — CC</td>
</tr>
<tr>
<td>CHART No.</td>
<td>42</td>
</tr>
<tr>
<td>SHEET No.</td>
<td>1 of 1</td>
</tr>
<tr>
<td>CHARTED BY</td>
<td>A. B.</td>
</tr>
<tr>
<td>DATE</td>
<td>25.10.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WINK COUNTER READING</th>
<th>LEFT HAND DESCRIPTION</th>
<th>TIME IN 2000/min.</th>
<th>RIGHT HAND DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>Finished part to tray</td>
<td>TL 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>TE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>UD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>To rubber tops</td>
</tr>
<tr>
<td>130</td>
<td>To bakelite caps</td>
<td>TE 16</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rubber tops</td>
</tr>
<tr>
<td>140</td>
<td>Bakelite cap</td>
<td>G 8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>To work area</td>
</tr>
<tr>
<td>150</td>
<td>To work area</td>
<td>TL 4</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>For assembling</td>
<td>P 2</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>RL 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TE 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>G 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>For R. H. to grasp top</td>
<td>P 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>U 6</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>RL 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TE 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>G 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>For R. H. to pull rubber top</td>
<td>H 14</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>U 8</td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

The simo chart is the micromotion form of the man type flow process chart. Because simo charts are used primarily for operations of short duration, often performed with extreme rapidity, it is generally necessary to compile them from films made of the operation which can be stopped at any point or projected in slow motion. It will be seen from the chart illustrated in figure 52 that the movements are recorded against time measured in “winks” (1 wink = 1/2000 minute). These are recorded by a “wink counter” placed in such a position that it can be seen rotating during the filming.

Motions are classified for each hand according to the list given in section 3 of this chapter. Some simo charts are drawn up listing the fingers used, wrist,

1 Adapted from Marvin E. Mundel: Motion and Time Study (New York, Prentice-Hall, Inc., 1950), p. 244.
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lower and upper arms. The hatching in the various columns represents the therblig colours associated with the movements, the letters refer to the therblig symbols.

We shall not go deeper into discussion of the simo chart. The reader is referred to the textbooks in the bibliography for further information, but he is advised not to try out micromotion study in practice without expert tuition and supervision.

11. THE USE OF FILMS IN METHODS ANALYSIS

The use of films in connection with work study is increasing rapidly, and they are now used widely both for the study of operations and for teaching.

In methods analysis films may be used for the following purposes:

1. MEMOMOTION PHOTOGRAPHY (A form of time lapse photography which records activity by a ciné camera adapted to take pictures at longer intervals than normal. The time intervals usually lie between ½ sec and 4 sec).

A camera is placed with a view over the whole working area to take pictures at the rate of one or two per second instead of the usual rate of 24 frames a second. The result is that the activities of 10 or 20 minutes may be compressed into one minute and a very rapid survey of the general pattern of movements may be obtained, from which the larger movements giving rise to wasted effort can be detected and steps taken to eliminate them. This method of analysis, which is a recent development, has considerable possibilities and is very economical.

2. MICROMOTION STUDIES.

These have already been touched upon in the preceding section. The advantages of films over visual methods are that they—

(a) permit greater detailing than eye observation;
(b) provide greater accuracy than pencil, paper and watch techniques;
(c) are more convenient;
(d) provide a positive record;
(e) help in the development of the work study men themselves.

Where short cycle operations are being studied it is usual to make the film into a loop so that the same operation can be projected over and over again. It is often necessary to project frame by frame, or
Movements at the Workplace

to hold one frame in position for some time. Special film viewers may be used.

Besides the analysis of methods, films can be very useful for

_RETRAINING OF OPERATIVES._

Both for this purpose and for analysis it may be necessary to have slow motion pictures of the process (produced by photographing at high speed); considerable use can be made of loops for this purpose.

12. OTHER RECORDING TECHNIQUES

It is convenient to describe here very briefly one or two other techniques of recording and analysis which have so far only been mentioned, and which will not be dealt with further in this introductory book.

Table 7 in Chapter 7 listed five diagrams indicating movement which are commonly used in method study. Three of these, the flow diagram, the string diagram and the travel chart, have already been described, with examples, in earlier chapters. The other two are the cyclegraph and the chronocyclegraph.

The _cyclegraph_ is a record of a path of movement, usually traced by a continuous source of light on a photograph, preferably stereoscopic. The path of movement of a hand, for instance, may be recorded on a photograph in this way if the worker is asked to wear a ring carrying a small light which will make the trace on the photograph. Or such a light may be attached to a worker's helmet if the purpose is to obtain a record of the path over which he moves during the performance of a task.

The _chronocyclegraph_ is a special form of cyclegraph in which the light source is suitably interrupted so that the path appears as a series of pear-shaped dots, the pointed end indicating the direction of movement and the spacing indicating the speed of movement. The application for these recording techniques is limited compared with those for the charts and diagrams illustrated in this book, but there are occasions on which photographic traces of this sort can be useful.

The only chart listed in table 7 which has not been described is the _P.M.T.S._ Chart—or Predetermined Motion Time System Chart to give it the full name. There are several Predetermined Motion Time System codes, all of which set out, through combinations of figures and letters, basic human motions and qualifying conditions with corresponding time values. All these systems make use of a breakdown of motions similar to therbligs. All of them are founded on the proposition that if an activity is broken down in sufficient detail into basic motions, times established elsewhere for those basic motions can be applied to synthesise a time for the activity under study. Like micromotion analysis, P.M.T.S. systems are valuable analysis tools in the hands of the specialist, but should not be attempted
Movement at the Workplace

by those who have not had the special training required, which itself should not be undertaken until the trainee has already had some considerable experience of method study work, followed by work measurement practice. P.M.T.S. systems are referred to again in Chapter 21 after time study techniques have been described.

13. THE DEVELOPMENT OF IMPROVED METHODS

In each of the examples of the different method study techniques given so far discussion has covered the three stages of RECORD, EXAMINE and DEVELOP, but has been focused primarily on the first two, the development stage being discussed only as far as was necessary to draw attention to the improvements made in method as a result of using the particular diagram or form being demonstrated.

It will now be appropriate to study a little more closely the manner in which improved methods can be developed.

Apart from the elimination of obviously wasteful movements—which can be done from the flow diagram or process chart—the development of improved methods calls for skill and ingenuity. It is likely to be more successful if the work study man is qualified as a technologist or by experience in the industry with which he is concerned. In any but the simplest manual operations he will have to consult with the technical or supervisory staff and, even if he does know the right answer, it is better that he should do so, since a method which they have taken part in developing is likely to be accepted more readily than one which is introduced as someone else's idea. The same is true of the operatives. Let everyone put forward his ideas—two heads are better than one!

The fact that really successful methods improvement is a combined operation has been increasingly widely recognised in the United States and Europe. Many organisations, large and small, have set up formal groups for the improvement of manufacturing and operating methods. These groups may be permanent or set up for some particular job such as the re-laying out of a shop or factory. In Sweden several enterprises have had success with such groups, which consist of a work study man, the foreman of the section in which the product is being manufactured, a product designer and a tool designer. The group meets regularly (once a month, for example) and discusses the analyses that have been prepared by the work study man. In this way it is possible not only to provide the work study man with the specialist information he needs but to get all the parties interested in the simplification work so that they feel a certain corporate responsibility for the results.

In the United Kingdom Joseph Lucas Ltd., manufacturers of electrical equipment and motor-car accessories, have developed similar groups at various levels which consider every aspect of manufacturing efficiency from designing the product for more economic production onwards through all the processes and methods.
The work which can be undertaken successfully by such groups has been taken a good deal further in recent years by the development of the technique known as value analysis, or value engineering. This is, in essence, the critical examination of a product, using practices developed and refined from method study as described in this book, with the intention of reducing the cost of manufacturing the product while at the same time maintaining or enhancing its value. In short, value analysis is method study applied to the product, but applied in a way which is essentially a team approach. It has produced some quite remarkable savings, not least in companies already noted for efficient working. Many such companies have concentrated on the adoption of increasingly mechanised methods, in the quest for higher labour productivity, but have not devoted the same close scrutiny to the material costs in their manufactures, until their eyes have been opened to the scope for savings through value analysis.

Despite the team approach used in many large companies, however, the major responsibility for the development of improved methods rests in most organisations with the work study man, and he must have a first-class knowledge and understanding of his subject.

The ability to devise “gadgets” is one of the most useful gifts a work study man can possess, since much wasted movement can often be eliminated by the introduction of a suitable jig, chute or other device.

An example of this is a small spring-loaded table, very cheaply made in plywood, for removing the tiles from an automatic tile-making machine. The spring was so calibrated that each time a tile was pushed on to it by the machine it was compressed until the top of the tile dropped to the level of the machine platform so that the table was ready to receive the next tile. This enabled the girl operating the machine to concentrate on loading the finished tiles onto a rack ready for firing while the new stack was piling up. When about a dozen tiles were in place she was able to lift them off the table, which immediately sprang up to the level of the machine platform ready to receive the first tile of the next stack. This very simple device enabled the second operator formerly employed on this operation to be released for other work, an important feature in an area where skilled tile-pressers were difficult to obtain.

One of the rewards of method study is the large savings which can often be made from quite small changes and inexpensive devices.

In many manufacturing plants the work study man may have to go beyond the study of the movements of materials and workers if he is going to make the most effective contribution to increased productivity. He must be prepared to discuss with the designers the possibility of using alternative materials which would make the product easier and quicker to manufacture. Even if he is not an expert in design—and, indeed, he cannot be expected to be—drawing attention to the possibilities of an alternative may put ideas into the minds of the designers them-
Movements at the Workplace

selves which they had previously overlooked. After all, like everyone else, they are human and often hard-worked, and there is a strong temptation to specify a given material for a given product or component simply because it has always been used in the past. The work study man who has been well grounded in method study practice should have little difficulty in initiating the value analysis approach in this way.

Similarly, the work study man will almost certainly be called upon to challenge the operation of the process, especially in metalworking shops where the machine tools are set up and run by operatives, sometimes according to process layouts devised by the process planning department, sometimes simply on their own or the foreman's knowledge and experience. The techniques of metalworking are advancing so quickly today that it is a pretty safe bet that in any machine shop, unless it has an exceptionally good process planning department, most of the machines will not be running at maximum efficiency, the general tendency being to run too slow, both in feeds and speeds. This will probably mean consultation with the foreman or shop manager, who regards himself (rightly or wrongly) as an expert and may resent being asked why the process is being operated in the way it is, and whether it is not possible to operate it faster, or in some other way. His immediate reaction will almost certainly be to say "No". This is where the tact and personality of the work study man have to be used to the full. Breaking down the conservatism of "experts" is an integral part of the work study man's job, and it is in this connection that the preliminary education of supervisors and others is so important: it not only acquaints them with the nature and purpose of work study but also makes them aware of the "questioning" approach and starts them thinking about things which previously they had taken for granted.

14. THE METHODS LABORATORY

There is great value in having a small room or shop where the work study men can develop and try out new methods. It need not be elaborate or expensive; many devices can be tried out in wood before they are manufactured in metal. If the scale of the work study activities justifies it, one or two good all-round craftsmen can be seconded to this laboratory with some simple tools, such as a drill press and sheet-metal equipment, together with a good operator from the production shops who will try out the different "gadgets" in collaboration with the work study staff until the best method has been found. Having such a place saves interfering with the production shops or the plant engineer's department when things are wanted in a hurry, and the work study staff feel much freer to try out revolutionary ideas. New methods can be demonstrated to management, foremen and operatives who can be encouraged to try them out and make suggestions to be incorporated in the final version.
Do not let the work study shop become the place where everyone in the works comes when they "want a little job done quickly" or private repairs executed. There is a real danger of this, as more than one company has discovered.

On no account may the operator attached to the work study shop be used for the setting of time standards. It is all right to time him in order to compare the effectiveness of different methods, but time studies for standard setting must always be made in the shops under production conditions with regular operatives.
DEFINE,
INSTALL,
MAINTAIN

1. OBTAINING APPROVAL FOR THE IMPROVED METHOD

Once a complete study of the job has been made, and the preferred new method developed, it is generally necessary to obtain the approval of the works management before proceeding to install it. The work study man should prepare a report giving details of the existing and proposed methods and should give his reasons for the changes suggested.

The report should show—

1. Relative costs in material, labour and overheads of the two methods, and the savings expected.
2. The cost of installing the new method, including the cost of any new equipment and of re-laying out shops or working areas, if this is required.
3. Executive actions required to implement the new method.
Define, Install, Maintain

Before it is finally submitted the report should be discussed with the departmental supervision or management; if the costs of the change are small and all are agreed that it is a useful change the work may proceed on the authority of the departmental manager or foreman.

If capital expenditure is involved, such as the purchase of materials handling equipment, or if complete agreement cannot be obtained from everyone concerned on the desirability of the change, then the matter may have to be taken to the works manager, and possibly by him to the managing director or managing agent, or even to the board of directors. In this case it is almost certain that the work study man will be called upon to justify his estimates. If capital investment is involved to any extent he will have to be able to convince doubting people, often non-technical, that it will really be justified. Great care must therefore be taken in preparing such estimates, since a failure to live up to them may damage both the work study man's own reputation and that of work study itself.

2. DEFINING THE APPROVED METHOD

The Written Standard Practice

For all jobs other than those performed on standard machine tools or specialised machines where the process and methods are virtually controlled by the machine it is desirable to prepare a written standard practice, also known as an "operator instruction sheet". This serves several purposes:

(1) It records the improved method for future reference, in as much detail as may be necessary.

(2) It can be used to explain the new method to management, foremen and operatives. It also advises all concerned, including the works engineers, of any new equipment required or of changes needed in the layout of machines or workplaces.

(3) It is an aid to training or retraining operatives and can be used by them for reference until they are fully conversant with the new method.

(4) It forms the basis on which time studies may be taken for setting standards, although the element breakdown will not necessarily be the same as the breakdown of motions.

The written standard practice outlines in simple terms the methods to be used by the operative. Therbligs and other method study symbols should not be used. Three sorts of information will normally be required—

1 See Chapter 15, section 6.
Define, Install, Maintain

FIGURE 53. STANDARD PRACTICE SHEET

PRODUCT:
3 mm diam. glass tube, supplied in 1 metre lengths

EQUIPMENT
Jig No. 231
Half-round 15 cm

OPERATION:
File and break to lengths of 1.5 cm

WORKING CONDITIONS:
Light good

LOCATION: Fitting shop

OPERATOR: D.G.
CLOCK No. 54
CHARTED BY: A.B.
APPROVED BY: C.R.
DATE: 23.7.52
DATE: 24.7.52

EL | LEFT HAND | RIGHT HAND | EL
---|-----------|------------|---
1  | Take tube between thumb and first two fingers: push forward to stop | Hold file: wait for L.H. | 1
2  | Rotate tube between thumb and fingers | Notch tube all round with edge of file hard up against face of jig | 2
3  | Hold tube | Tap notched end of tube sharply with file so that it falls into chute | 3
Define, Install, Maintain

(1) The tools and equipment to be used and the general operating conditions.

(2) A description of the method. The amount of detail required will depend on the nature of the job and the probable volume of production. For a job which will occupy several operators for several months the written standard practice may have to be very detailed, going into finger movements.

(3) A diagram of the workplace layout and, possibly, sketches of special tools, jigs or fixtures.

A very simple written standard practice for the operation studied in Chapter 11, Section 7 (cutting glass tubes to length), is illustrated in figure 53. The same principle is followed in more complex cases. In some of these the description may run into several pages. The workplace layout and other diagrams may have to be put on a separate sheet. With the more widespread use in recent years of printed sheets for process charts, in standard form, it is becoming common practice to attach a fair copy of the appropriate process chart to the written standard practice, whenever the simple description entered thereon does not constitute a complete definition of the method.

3. INSTALLING THE IMPROVED METHOD

The final stages in the basic procedure are perhaps the most difficult of all. It is at this point that active support is required from management and trade unions alike. It is here that the personal qualities of the work study man, his ability to explain clearly and simply what he is trying to do and his gift for getting along with other people and winning their trust become of the greatest importance.

Installation can be divided into five stages, namely—

(1) Gaining acceptance of the change by the departmental supervision.

(2) Gaining approval of the change by works and general management.

These two steps have already been discussed. It is little use trying to go any further unless they have been successful.

(3) Gaining acceptance of the change by the workers involved and their representatives.

(4) Retraining the workers to operate the new methods.

(5) Maintaining close contact with the progress of the job until satisfied that it is running as intended.
If any changes are proposed which affect the number of workers employed in the operation—as is often the case—then the workers' representatives should be consulted as early as possible. Plans for any displacement of labour must be very carefully worked out so that the least hardship or inconvenience is caused. Remember, even on a one-man operation, the worker in a workshop or any other organisation does not work in isolation. If he is not a member of a team for the specific purpose of his job, he is a member of a section or department; he gets used to having the same people working around him, to spending his meal breaks with the same "gang". Even if he is too far away from them to carry on a conversation during his work, he can see them; he can, perhaps, exchange a joke with them from time to time or grouse at the management or the foreman. He adjusts his personality to them and they to him. If he is suddenly moved, even if it is only to the other end of the shop, his social circle is broken up, he feels slightly lost without them and they without him.

In the case of a team or gang working together the bonds are far stronger, and breaking up such a team may have serious effects on productivity, in spite of improved methods. It is only since the nineteen-thirties that the importance of social groups and relationships in the factory and working area has come to be recognised. Failure to take this into account may lead the workers to resist changes which they would otherwise accept.

It is in carrying out the first three steps of installation that the importance of preliminary education and training in work study for all those likely to be concerned with it—management, supervisors and workers' representatives—becomes evident. People are much more likely to be receptive to the idea of change if they know and understand what is happening than if they are merely presented with the results of a sort of conjuring trick.

Where redundancy or a transfer are not likely to be involved, the workers are much more likely to accept new methods if they have been allowed to share in their development. The work study man should take the operator into his confidence from the start, explaining what he is trying to do and why, and the means by which he expects to do it. If the operator shows an intelligent interest the uses of the various tools of investigation should be explained. The string diagram is one of the most useful of these in gaining interest: most people like to see their activities portrayed, and the idea that he walks so far in the course of a morning's work is often a surprise to the worker and makes him delighted with the idea of reducing his efforts. Always ask the worker for his own suggestions or ideas on improvements that can be made, and wherever they can be embodied, do so, giving him the credit for them (major suggestions may merit a monetary reward). Let him play as full a part as possible in the development of the new method, until he comes to feel it is mainly or partly his own.

It may not always be possible to obtain very active co-operation from unskilled personnel, but even they usually have some views on how their jobs can be made
Define, Install, Maintain
easier—or less subject to interruption—which may give important leads to the
work study man in reducing wasted time and effort.

Wholehearted co-operation at any level will only come as the result of con-

fidence and trust. The work study man must convince the management that he
knows what he is doing. He must have the respect of the supervisors and techni-
cians, and they must realise that he is not there to displace them or show them up,
but as a specialist at their disposal to help them. Finally, he must convince the work-
ers that he is not going to harm them.

Where there is deep-rooted resistance to change it may be necessary to decide
whether the savings likely to be made by adopting the new method justify the time
and trouble involved in putting the change through and retraining older operators.
It may be cheaper to concentrate on new trainees and let the older ones continue
to work in the way they know.

The work study man occupies a strange position in a firm which has not before
practised modern management. It was said earlier (in Chapter 5) that in the in-
dustrialised countries of the western world the work study specialist was often
the pioneer of modern, enlightened personnel management. This is likely to be the
case in many of the countries to which this book will find its way, especially in
those developing countries where labour is not strongly organised or the workers’
representatives lack the knowledge and education needed to negotiate with the
management on technical matters. The work study man, although he is an em-
ployee of the management, may often have to represent the workers’ point of view
to management, pointing out the risks or hardships involved in certain courses of
action. He will sometimes be overruled, and there is little that he can do about it
except try again; but if he can show that if his ideas and his methods are adopted
results beneficial to the firm will follow, then he may gradually gain his way.

In gaining the trust of the workers the work study man will find that they
will tend to turn to him for decisions rather than to the foreman (a danger already
discussed); this is a situation which must not be allowed to arise. He must make
certain from the first that everyone understands that the work study man cannot
give executive decisions and that the instructions concerning the introduction and
application of the new methods must come from the foreman to the worker in the
first instance. Only then can he proceed.

4. TRAINING AND RETRAINING OPERATIVES

The extent to which the workers require retraining will depend entirely on the
nature of the job. It will be greatest in the case of jobs involving a high degree of
manual dexterity which have long been done by traditional methods. In such
cases it may be necessary to resort to films to demonstrate the old and the new
methods and the manner in which movements should be made. Each job will
have to be treated on its merits.
In the training or retraining of operatives the important thing is to develop the habit of doing the job in the correct way. Habit is a valuable aid to increased productivity as it reduces the need for conscious thought. Good habits can be formed just as easily as bad ones.

Beginners can be taught to follow a numbered sequence illustrated on a chart or they may be taught on the machine itself. Either way, they must be made to understand the reason for every movement. Still pictures together with instruction sheets have proved very successful. Film strips can also be used.

Films are particularly valuable when retraining. In breaking old habits it may be found that the operator is quite unaware of what he or she is doing. A film in slow motion will enable him to see his exact movements and, once he knows, he can start to learn the new method. It is important that the new method should be really different from the old, otherwise the operator will tend to slip back into his old ways, especially if he is not young and has spent many years doing the job.

In learning a new series of movements the operator gathers speed and reduces the time required to perform them very quickly at first, but the rate of improvement soon begins to slow up, and it often requires long practice to achieve really high and consistent speed, although the adoption of modern accelerated training methods will considerably shorten the time needed. A typical "learning curve" is shown in figure 54.

FIGURE 54. A TYPICAL LEARNING CURVE
Experiments have shown that in the first stages of learning, to obtain the best results, rests between periods of practice should be longer than the periods of practice themselves. This situation alters rapidly, however, and once the operator has begun to grasp the new method and to pick up speed rest periods can be very much shorter.

Part of the process of installation is keeping in close touch with the job once it has been started to ensure that the operator is developing speed and skill and that there are no unforeseen snags arising. This activity is often known as "nursing" the new method, and the term is an apt one. Only when the work study man is satisfied that the productivity of the job is at least that which he estimated and that the operator has settled down to it can it be left—for a time.

5. MAINTAINING THE NEW METHOD

It is important that, once a method is installed, it should be maintained in its specified form, and that workers should not be allowed to slip back into old methods or introduce elements not allowed for unless there is very good reason for doing so.

To be maintained, a method must first be very clearly defined and specified. This is especially important where it is to be used for setting time standards for incentive or other purposes. Tools, layout and elements of movement must be specified beyond any risk of misinterpretation. The extent to which it is necessary to go into minute details will be determined by the job itself.

Action by the work study department is necessary to maintain the application because, human nature being what it is, workers and foremen or chargehands will tend to allow a drift away from the method laid down if there is no check. Many disputes over time standards arise because the method being followed is not the one for which the time was specified; foreign elements have crept in. If the method is properly maintained this cannot happen. If it is found that an improvement can be made in the method (and there are very few methods which cannot be improved in time, often by the operator himself), then this should be officially incorporated, a new specification drawn up and new time standards set.

6. CONCLUSION

In this and the preceding chapters an attempt has been made to explain and illustrate some of the more common methods of improving productivity through the saving of wasted effort and time, and by reducing the work content of the process. Good method studies will do more than this, because they will draw attention to waste of material and waste of capital invested in equipment.
In the chapters which follow we shall discuss work measurement. This is one of the principal tools of investigation by which sources of ineffective time can be disclosed. It is also the means of setting time standards on which planning and control of production, incentive schemes and labour cost control data can be based. All these are powerful tools for reducing ineffective time and for raising productivity.
PART THREE

WORK MEASUREMENT
CHAPTER 13

GENERAL REMARKS ON WORK MEASUREMENT

1. DEFINITION

In Chapter 4 it was said that work study consists of two complementary techniques—method study and work measurement. In that chapter both were defined, and before going on to discuss work measurement it is worth while repeating the definition given there.

Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.

1 The relationship between them was shown in figure 7 (p. 42).
General Remarks on Work Measurement

There are several features of this carefully thought-out definition which we shall have occasion to examine in more detail in later chapters. For instance, the reader will have noted the references to "a qualified worker", and to "a defined level of performance". We need not concern ourselves with the exact meanings of these terms for the moment. It is worth noting, however, that the term "work measurement", which we have referred to hitherto as a technique, is really a term used to describe a family of techniques any one of which can be used to measure work, rather than a single technique by itself. The principal techniques which are classed as work measurement techniques are listed in section 4 of this chapter.

2. THE PURPOSE OF WORK MEASUREMENT

In Chapter 2 we discussed the way in which the total time of manufacture of an article was increased by undesirable features of the product itself, by bad operation of the process and by ineffective time added in the course of production owing to shortcomings on the part of the management or to actions of the workers. All these factors tended to reduce the productivity of the enterprise.

In Chapter 3 we discussed the management techniques by which these factors could be eliminated or, at any rate, reduced. Method study has been shown to be one of the principal techniques by which the work involved in the product or the process could be decreased by the systematic investigation and critical examination of existing methods and processes and the development and installation of improved methods.

Reference to figures 4 and 5 shows, however, that the reduction of the actual work involved in product or process to the minimum possible takes us only part of the way towards achieving maximum productivity from the resources of manpower and plant available. Even if the essential work is reduced to the minimum there is quite likely to be a great deal of unnecessary time taken in the course of manufacture due to the failure of the management to organise and control as efficiently as it might and, beyond that, further time wasted through the action or inaction of workers.

Method study is the principal technique for reducing the work involved, primarily by eliminating unnecessary movement on the part of material or operatives and by substituting good methods for poor ones. Work measurement is concerned with investigating, reducing and subsequently eliminating ineffective time, that is time during which no effective work is being performed, whatever the cause.

Work measurement, as the name suggests, provides management with a means of measuring the time taken in the performance of an operation or series of operations in such a way that ineffective time is shown up and can be separated from effective time. In this way its existence, nature and extent become known where

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1 See pp. 22 and 28.
previously they were concealed within the total. One of the surprising things
about factories where work measurement has never been employed is the amount
of ineffective time whose very existence is unsuspected—or which is accepted as
"the usual thing" and something inevitable that no one can do much about—
built into the process. Once the existence of ineffective time has been revealed
and the reasons for it tracked down steps can usually be taken to reduce it.

Here work measurement has another role to play. Not only can it reveal
the existence of ineffective time; it can also be used to set standard times for carrying
out the work, so that if any ineffective time does creep in later on it will immediately be shown up as an excess over the standard time and will thus be brought
to the attention of the management.

In Chapter 4 work study was spoken of as a "surgeon's knife". Method study
is the "knife" used to reveal shortcomings of design, material and method of manufacture, and, as such, affects mainly technical people. Work measurement is
more likely to show up management itself and the behaviour of the workpeople. Because of this it is apt to meet with far greater resistance than method study.
Nevertheless, if the efficient operation of the enterprise as a whole is being sought, the application of work measurement, properly carried out, is one of the best
means of achieving it.

It is unfortunate that work measurement, and in particular time study, its
principal technique, acquired a bad reputation in the past, especially in trade union circles. This was because in many early applications it was directed almost
exclusively to reducing the ineffective time within the control of the operatives by setting standards of performance for them, while the ineffective time within the
control of management was virtually ignored. The causes of ineffective time over
which management has some control are much more numerous than those which lie within the direct control of the workers. Furthermore, experience has shown
that if causes of ineffective time such as hold-ups due to lack of raw materials or
to plant breakdowns are allowed to go on without real efforts being made to eliminate them, operatives tend to get discouraged and slack, and "workers' ineffective time" increases. This is only to be expected: the attitude taken by the workers is, quite simply: "Well, if we are going to be stopped from doing our jobs by something which we can do nothing about and which it is the management's job to put right, why should we work harder? Let the management put its own house in order first." It is an argument that can hardly be countered.

Just as method study should precede work measurement in any reorganisation
that takes place, so must the elimination of ineffective time due to management shortcomings precede any attack on the ineffective time within the control of the workers. Indeed, the mere fact of reducing the hold-ups and stoppages within the control of the management will tend to reduce the waste of time by the operatives, because they will find themselves faced with proper supplies of work and of material, and will have the general feeling that management is "on its toes". This
General Remarks on Work Measurement

will in itself have a beneficial effect without the application of incentive schemes or of any form of coercion.

**Work measurement may start a chain reaction throughout the organisation.** How does this come about?

The first thing to realise is that breakdowns and stoppages taking effect at the shop floor level are generally only the end results of a series of management actions or failures to act.

Let us take an example of excessive idle time of an expensive machine, revealed by a study taken over several days (known as a “production study”).¹ This piece of plant is very productive when operating but takes a long time to set up. It is found that a great deal of the idle time is due to the batches of work which are being put on this machine being very small, so that almost as much time is spent in resetting it to do new operations as is spent in actual production. The chain of reactions resulting from this discovery may be something like this:

- **The Work Study Department**
  - reports that work measurement reveals that the machine is idle for excessively long periods owing to small orders coming from the planning office. This is substantially increasing the cost of manufacture. It suggests that the planning office do some proper planning and either combine several orders for the same product into one large order or make more for stock.

- **The Planning Office**
  - complains that it has to work on the instructions of the sales office, which never seems to sell enough of any one product to make up a decent-sized batch and cannot give any forecast of future orders so that more can be made for stock.

- **The Sales Office**
  - says that it cannot possibly make forecasts or provide large orders of any one product as long as it remains the policy of top management to accept every variation that customers like to ask for. Already the catalogue is becoming too large: almost every job is now a “special”.

- **The Managing Director**
  - when the effect of his marketing policy (or lack of it) on the production costs is brought to his attention is surprised and says

¹ See Chapter 21.
General Remarks on Work Measurement

that he never thought of it like that; all he was trying to do was to prevent orders going to his competitors by being as obliging to his customers as possible.

One of the principal purposes of work study will have been served if the original investigation leads the managing director to think again about his marketing policy. Enthusiastic work study men may, however, find it well to pause a moment and think about the fact that such chains of reaction tend to make someone ask: “Who started this, anyway?” People do not like being “shown up”. This is one of the situations in which a good deal of tact may have to be used. It is not the work study man’s job to dictate marketing policy, but merely to bring to the attention of management the effect of that policy on the company’s costs and hence on its competitive position.

Thus it can be seen that the purposes of work measurement are to reveal the nature and extent of ineffective time, from whatever cause, so that action can be taken to eliminate it; and then to set standards of performance of such a kind that they will be attainable only if all avoidable ineffective time is eliminated and the work is performed by the best available method and by personnel suitable in training and ability to their tasks.

We can now go on to discuss in greater detail the uses and techniques of work measurement.

3. THE USES OF WORK MEASUREMENT

Revealing existing causes of ineffective time through study, important though it is, is perhaps less important in the long term than the setting of sound time standards, since these will continue to apply as long as the work to which they refer continues to be done and will show up any ineffective time or additional work which may occur once they have been established.

In the process of setting standards it may be necessary to use work measurement—

(a) To compare the efficiency of alternative methods. Other conditions being equal, the method which takes the least time will be the best method.

(b) To balance the work of members of teams, in association with multiple activity charts, so that, as nearly as possible, each member has a task taking an equal time to perform (see Chapter 10, Section 4).

(c) To determine, in association with man and machine multiple activity charts, the number of machines an operative can run (see Chapter 10, Section 4).
WORK MEASUREMENT

to provide a yardstick for human effort

SELECT
work to be measured

RECORD
all relevant data, breaking the job down into elements

EXAMINE
the method and breakdown critically

MEASURE
quantity of work involved by

P.M.T.S. or TIME STUDY or ACTIVITY SAMPLING or SYNTHESIS

Time and record each element

Compile
Extend
Summarise like elements
Select basic times for each element

or

ANALYTICAL ESTIMATING

Apply established element values and estimate others

Compile
Total basic times

adding relaxation allowance and other justifiable allowances to give

STANDARD UNIT OF WORK
i.e., STANDARD HOUR OR STANDARD MINUTE

DEFINE
precisely the activities covered and issue the standard time

to achieve

Improved planning and control
More efficient manning of plant
Reliable indices for labour performance
Reliable basis for labour cost control

Reliable basis for financial incentives

HIGHER PRODUCTIVITY
General Remarks on Work Measurement

The time standards, once set, may then be used—

(d) To provide information on which the planning and scheduling of production can be based, including the plant and labour requirements for carrying out the programme of work and the utilisation of available capacity.

(e) To provide information on which estimates for tenders, selling prices and delivery promises can be based.

(f) To set standards of machine utilisation and labour performance which can be used for any of the above purposes and as a basis for incentive schemes.

(g) To provide information for labour-cost control and to enable standard costs to be fixed and maintained.

It is thus clear that work measurement provides the basic information necessary for all the activities of organising and controlling the work of an enterprise in which the time element plays a part. Its uses in connection with these activities will be more clearly seen when we have shown how the standard time is obtained.

4. THE TECHNIQUES OF WORK MEASUREMENT

The following are the principal techniques by which work measurement is carried out:

- time study;
- activity sampling, and its extension, rated activity sampling;
- synthesis from standard data;
- predetermined motion time systems;
- estimating;
- analytical estimating;
- comparative estimating.

Of these techniques we shall concern ourselves primarily with time study, since it is the basic technique of work measurement. Some of the other techniques either derive from it or are variants of it. Each of the techniques listed above will be defined and described in subsequent chapters, though the three estimating techniques will be discussed only briefly. For the next few chapters we shall be considering only the fundamental technique of time study.
5. THE BASIC PROCEDURE

In section 5 of Chapter 4 we described the basic steps of work study, embracing both method study and work measurement. The basic procedure of method study has been described separately in figure 8 (page 78) and in the text on pages 76–77. We shall now isolate those steps which are necessary for the systematic carrying out of work measurement. These steps and the techniques necessary for achieving them are shown diagrammatically in figure 55. They are—

- **SELECT** the work to be studied.
- **RECORD** all the relevant data relating to the circumstances in which the work is being done, the methods and the elements of activity in them.
- **EXAMINE** the recorded data and the detailed breakdown critically to ensure that the most effective method and motions are being used and that unproductive and foreign elements are separated from productive elements;
- **MEASURE** the quantity of work involved in each element, in terms of time, using the appropriate work measurement technique.
- **COMPARE** the standard time for the operation which will include time allowances to cover relaxation, personal needs, contingencies, etc.
- **DEFINE** precisely the series of activities and method of operation for which the time has been compiled and issue the time as standard for the activities and methods specified.

It will only be necessary to take the full range of steps listed above if a time is to be published as a standard. When work measurement is being used only as a tool of investigation of ineffective time before or during a method study, or to compare the effectiveness of alternative methods, only the first four steps are likely to be needed.

In the following chapters these steps and the activities entailed in carrying them out will be discussed in detail.

---

1. WHAT IS TIME STUDY?

In the previous chapter we listed the main techniques of work measurement. We now come to the most important of these techniques, namely time study.

Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.

2. BASIC TIME STUDY EQUIPMENT

In order to make time studies certain equipment is essential. Basic time study equipment consists of—
Time Study Equipment

- a stopwatch;
- a study board;
- pencils;
- time study forms.

This equipment the studyman will need with him whenever he makes a time study. In addition there should be in the study office—

- slide rules;
- a reliable clock, with seconds hand;
- measuring instruments such as tape measure, steel rule, micrometer, spring balance, and tachometer (revolution counter). Other measuring instruments may be useful, depending on the type of work being studied.

It is an advantage to have in the study office also—

- an adding machine, or simple form of calculating machine.

The Stopwatch

Two types of watch are in general use for time study, namely the flyback and the non-flyback types. A third type—the split-hand stopwatch—is sometimes used.

These watches may be obtained with any one of three graduated scales—

1. Recording one minute per revolution by intervals of one-fifth of a second, with a small hand recording 30 minutes.

2. Recording one minute per revolution calibrated in 1/100ths of a minute, with a small hand recording 30 minutes (the decimal-minute watch).

3. Recording 1/100th of an hour per revolution graduated in 1/10,000ths of an hour; a small hand records up to one hour in 100 divisions (the decimal-hour watch).

It is also possible to obtain watches with the main scale in decimal minutes and an auxiliary scale outside it, usually in red, graduated in seconds and fifths of a second.

A flyback decimal minute stopwatch—probably the type in most general use today—is shown in figure 56. The hand of the small dial makes 1/30th of a revolution for each revolution of the main hand, and thus makes a complete turn every 30 minutes.
In this type of watch the movement is started and stopped by a slide (A) at the side of the winding-knob (B). Pressure on the top of the winding-knob causes both the hands to fly back to zero without stopping the mechanism, from which point they immediately move forward again. If the slide is used the hands can be stopped at any point on the dial and restarted without returning to zero as soon as the slide is released. This type of watch can be used for either "flyback" or "cumulative" timing (see Chapter 15, Section 8).

The non-flyback type is controlled by pressure on the top of the winding-knob. The first pressure starts the watch; the second pressure stops it; the third pressure returns the hands to zero. This watch is suitable only for cumulative timing.

In the split-hand type of watch, depressing a secondary knob causes one of the hands to stand still while the other continues to measure time. A second depression returns the stopped hand to the moving one and the two go on together. In this way a stopped hand is read when a reading is taken instead of a moving one, giving greater accuracy of reading.

I.L.O. experts in the field have taught staffs of national productivity centres to use all these types of watches, with equal success. The split-hand watch is easier to read, but is heavier, more expensive, and, because of its complexity, more
Time Study Equipment

Troublesome to repair—a factor of considerable importance in many developing countries. With properly trained study men, equally good results can be obtained with a simpler, lighter and less expensive watch. Unless there are special reasons for preferring one of the other types, the single-pressure, centre-sweep hand, flyback watch with the main dial graduated in $1/100$ths of a minute and the smaller dial recording 30 minutes, will be found most serviceable for time study. This is the type illustrated in figure 56. It may take readers a little time to learn to think in decimal minutes instead of in seconds, but they will very soon become accustomed to doing so.

Whatever type of watch is used it should always be remembered that it is a delicate instrument which must be treated with care. Watches should be wound fully before each study, and should be allowed to run down overnight. At regular intervals they should be sent to a watchmaker for cleaning and routine overhaul.

The Study Board

The study board is simply a flat board, usually of plywood or of suitable plastic sheet, on which to place the forms for recording time studies. It should be rigid and larger than the largest form likely to be used. It may have a fitting to hold the watch so that the hands of the work study man are left relatively free and the watch is in a position to be read easily. For right-handed people the watch is normally placed at the top of the board on the right-hand side so that the board may be rested on the left forearm with the bottom edge against the body and the forefinger or middle finger of the left hand used to press the winding knob when resetting the watch (see figure 57). Some work study men prefer to attach their watches with strong rubber bands or leather thongs around the two middle fingers of their left hands and to hold them at the top of the board in that way. It is largely a matter of individual preference, provided that the watch is securely held and can be easily read and manipulated. A strong spring clip should also be fitted to the board to hold the forms on which the study is recorded.

A study board which is either too short for the study man’s arm, or too long, soon becomes tiring to use. Most study men prefer therefore to have their own individual boards made up to fit their own arm lengths, once they have had sufficient practice to know which size will be most comfortable.

Pencils

The study man should carry with him at least two pencils when he leaves the office to make a study. If he has only one, a broken point will mean breaking off the study until it has been sharpened again. Pencils should be on the hard side; HB is generally too soft. H and 2H grades are more suitable.
FIGURE 57. TIME STUDY BOARDS

(a) Study board for general purpose form

(b) Study board for short cycle form
3. TIME STUDY FORMS

Studies can be made on plain paper, but it is a nuisance having to rule up new sheets every time a study is made. It is a great convenience to have printed forms of a standard size so that they can be filed neatly for reference, an essential feature of well-conducted time study. Printed—or cyclostyled—forms also ensure that time studies are always made in a standard manner and that no essential data are omitted.

The number of different designs of time study forms is probably not far short of the number of work study departments in the world. Most experienced work study men have their own ideas on the ideal layout. The examples shown in this book represent designs which have been proved in practice to be satisfactory for general work.

The principal forms used in time study fall into two groups: those used at the point of observation while actually making the study, and which should therefore be of a size to fit conveniently on the studyboard; and those which are used after the study has been taken, in the study office.

Forms Used on the Study Board

- **Time study top sheet**: the top and introductory sheet of a study, on which is recorded all the essential information about the study, the elements into which the operation being studied has been broken down, and the break points used. It may also record the first few cycles of the study itself. The example shown in figure 58 has spaces in the heading for all the information normally required about a study except the sketch of the workplace layout, which should either be drawn on the reverse of the sheet, if the layout is very simple, or should be drawn on a separate sheet (preferably of squared paper) and attached to the study.

- **Continuation sheet**: for further cycles of the study. An example is shown in figure 59, from which it will be seen that the form consists only of the columns and space for the study and sheet number. It is usual to print this ruling on both sides of the paper; on the reverse side the heading is not necessary.

These two forms are the ones most generally used. Together they are adequate for most general time study work. For the recording of short cycle repetitive operations, however, it is convenient to use instead a specially ruled form.

- **Short cycle study form**: Two examples of a short cycle form are illustrated. That in figure 60 shows a simple type of form which serves very well for most common short cycle work. The other, shown (front) in figure 61 and (reverse) in figure 62, is a more complicated form, adapted from one in general use in the United States, which may be more suitable if short cycle work is the rule rather than the exception.¹

¹ Included by permission of the Productivity Centre of the Indian Ministry of Labour.
**TIME STUDY TOP SHEET**

<table>
<thead>
<tr>
<th>DEPARTMENT:</th>
<th>STUDY No.:</th>
<th>M.S. No.:</th>
<th>SHEET No.:</th>
<th>OPERATOR:</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATION:</td>
<td>STUDY No.:</td>
<td>M.S. No.:</td>
<td>SHEET No.:</td>
<td>OPERATOR:</td>
</tr>
<tr>
<td>PLANT/MACHINE:</td>
<td>No.:</td>
<td>TIME ON:</td>
<td>ELAPSED TIME:</td>
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<tr>
<td>TOOLS AND GAUGES:</td>
<td>No.:</td>
<td>OPERATOR:</td>
<td>CLOCK No.:</td>
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<tr>
<td>PRODUCT/PART:</td>
<td>No.:</td>
<td>STUDIED BY:</td>
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<td>DWG. No.:</td>
<td>MATERIAL</td>
<td>DATE:</td>
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<tr>
<td>QUALITY:</td>
<td>CHECKED:</td>
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*N.B. Sketch the WORKPLACE LAYOUT/SET-UP/PART on the reverse, or on a separate sheet and attach

<table>
<thead>
<tr>
<th>ELEMENT DESCRIPTION</th>
<th>R.</th>
<th>W.R.</th>
<th>S.T.</th>
<th>B.T.</th>
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<thead>
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<th>R.</th>
<th>W.R.</th>
<th>S.T.</th>
<th>B.T.</th>
</tr>
</thead>
</table>

FIGURE 59. CONTINUATION SHEET FOR GENERAL-PURPOSE TIME STUDY (Front)

<table>
<thead>
<tr>
<th>STUDY No.:</th>
<th>TIME STUDY CONTINUATION SHEET</th>
<th>SHEET No.</th>
<th>OF</th>
</tr>
</thead>
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</tbody>
</table>

**N.B.** Reverse side similar, but without upper line of heading.
## FIGURE 60. SIMPLE TYPE OF SHORT CYCLE STUDY FORM

### SHORT CYCLE STUDY FORM

<table>
<thead>
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<th>DEPARTMENT:</th>
<th>SECTION:</th>
<th>STUDY No.:</th>
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<tr>
<td></td>
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<td>SHEET No.:</td>
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<td>OF:</td>
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<tr>
<td>OPERATION:</td>
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<td>TIME OFF:</td>
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<td>PLANT/MACHINE:</td>
<td>No.</td>
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<td>TOOLS AND GAUGES:</td>
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<td>MATERIAL:</td>
<td>CLOCK No.:</td>
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<td>WORKING CONDITIONS:</td>
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<td>DATE:</td>
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<td></td>
<td>CHECKED:</td>
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N.B. Sketch the workplace overleaf.

<table>
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<th>EL No.</th>
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<th>Observed Time</th>
<th>Total O.T.</th>
<th>Average O.T.</th>
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<th>B.T.</th>
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</table>

N.B. R = Rating. O.T. = Observed Time. B.T. = Basic Time.
### SHORT CYCLE STUDY SHEET

<table>
<thead>
<tr>
<th>DATE OF STUDY</th>
<th>TIME FINISHED</th>
<th>TIME STARTED</th>
<th>ELAPSED TIME</th>
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<table>
<thead>
<tr>
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<th>DWG. No</th>
<th>PART No.</th>
<th>BASIC CYCLE TIME</th>
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<td>MINS.</td>
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<td></td>
<td>OR</td>
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<table>
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<tr>
<th>OPERATION:</th>
<th>SPEED:</th>
<th>FEED</th>
<th>R.P.M.</th>
<th>TOTAL AVE. ELEMENT TIME</th>
<th>RATING FACTOR</th>
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<table>
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<th>ALLOWANCES</th>
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<td>DELAY %</td>
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<td>FATIGUE %</td>
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<td>OTHERS %</td>
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<table>
<thead>
<tr>
<th>MACHINE AND No.</th>
<th>OPERATED:</th>
<th>MATERIAL</th>
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<tbody>
<tr>
<td></td>
<td>AUTO ☐</td>
<td>FOOT ☐</td>
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<td></td>
<td>HAND ☐</td>
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<thead>
<tr>
<th>WORKPLACE LAYOUT</th>
<th>DESCRIPTION OF METHOD</th>
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TO CHECK ESTAB. STANDARD ☐

STANDARD TIME PER PIECE: MINS.

REMARKS:
**SHORT CYCLE STUDY SHEET**

<table>
<thead>
<tr>
<th>STUDY No.</th>
<th>SHT.</th>
<th>OF SHTS.</th>
<th>CLOCK No.</th>
<th>OBSERVED BY</th>
<th>APPROVED BY</th>
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**FOREIGN ELEMENTS**

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**FIGURE 62. SHORT CYCLE STUDY FORM (Back)**

(ADAPTED FROM FORM USED BY GOVERNMENT OF INDIA, MINISTRY OF LABOUR, PRODUCTIVITY CENTRE)
The international standard A4 size of paper is a good one to use for these forms, as it is about the biggest standard size which will fit conveniently on a study board. Foolscap is generally found to be a little too long.

**Forms Used in the Study Office**

- **Working sheet**: for analysing the readings obtained during the study and obtaining representative times for each element of the operation. One example of a working sheet is shown in figure 83 in Chapter 19. As will be seen later, there are various ways in which the analysis may be made, each requiring a different ruling on the sheet. For this reason many studymen prefer to use simple lined sheets, of the same size as the study sheets, for making their analyses, clipping these to the study sheets when complete.

- **Study summary sheet**: to which the selected or derived times for all the elements are transferred, with the frequencies of the elements' occurrence. This sheet, as its name suggests, summarises neatly all the information which has been obtained during the course of the study. The heading includes all the details recorded about the operation at the top of the time study top sheet. The completed study summary sheet is clipped onto the top of all the other study sheets and is thus filed with them. The summary sheet should therefore be of the same size as that chosen for the study sheets. An example is shown in figure 63 and it will be seen from this that the main body of the sheet has space for the ruling of additional columns, should these be needed for the particular study being summarised.

- **Analysis of studies sheet**: on which are recorded, from the study summary sheets, the results obtained in all the studies made on an operation. The analysis of studies sheet records the results of all the studies made of a particular operation, no matter when they were made or by whom. It is from the analysis of studies sheet that the basic times for the elements of the operation are finally compiled. The sheet is often much larger than the ordinary study forms. See figure 64 and figure 85 in Chapter 19.

- A specially ruled sheet for the compilation of Relaxation Allowances is often used. An example is shown in figure 86.

The use of all these forms, both those employed when actually making the study and those used afterwards to analyse and record it will be described in detail in subsequent chapters.

**4. OTHER EQUIPMENT**

Apart from the stopwatch, there are other timing devices which are used when very accurate measurement is required. They will not be discussed in detail in this book as the stopwatch provides the accuracy necessary for the work that most readers are likely to undertake during the first few years of their application of work measurement techniques. Two of them may, however, be mentioned.
## STUDY SUMMARY SHEET

<table>
<thead>
<tr>
<th>ELEMENT No.</th>
<th>ELEMENT DESCRIPTION</th>
<th>B.T.</th>
<th>F.</th>
<th>Obs.</th>
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</tbody>
</table>

*N.B.* B.T. = Basic Time.  F. = Frequency of occurrence per cycle.  Obs. = No. of observations
## ANALYSIS OF STUDIES SHEET

**OPERATION:**

**DETAILS OF MACHINE, MATERIALS, ETC.:**

- Study No.
- Date made
- Operative
- Clock No.
- Machine No.

**DEPARTMENT**

**SECTION**

<table>
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<th>B.M.</th>
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**N.B.** El. = Element  B.M. = Basic Minutes  S.M. = Standard Minutes
(a) The motion picture camera running at a constant speed, the film being projected at an equal constant speed.

(b) The time study machine. In this machine marks are made on a paper tape running at constant speed by pressure of the fingers on two keys. Its only advantage over the stopwatch is that it leaves the work study man free to observe the operation continuously instead of having to look at and read the watch. It also enables very short elements to be timed. The tape has to be measured on completing the study.

Among the equipment listed in section 2 was a reliable clock, with seconds hand, for use in the study office. Before leaving the office to make a study, the studyman starts his stopwatch and notes on his study sheet the time by the office clock at which he did so. If the studyman has wrist watch it can be used instead, provided it is reliable. In any case it is often an advantage for the studyman to have a wrist watch, though not essential.

The time study office will need the usual clerical equipment—staplers, punches, files and cabinets of some sort to put them in, and so on. It is very useful to have an office-type pencil sharpener fixed somewhere near the door of the study office.

Besides the measuring equipment mentioned in Section 2, other instruments may be found useful in particular trades. One instrument with a fairly wide application is the Servis Recorder, which can be attached to a machine or vehicle and will then make a record of when the machine it is placed on is in motion, and when stopped. A micrometer is often useful: reliable ones can now be obtained quite cheaply. Thermometers are often essential, and, in hotter climates, the wet kata thermometer especially.

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1 The use of the wet kata thermometer is described in Appendix 6.
SELECTING THE JOB TO BE STUDIED AND MAKING A TIME STUDY

1. SELECTING THE JOB TO BE STUDIED

As in method study, the first step in time study is to select the job to be studied. Generally speaking, there are few occasions when a work study man can go into a factory or a department and select a job at random. There is nearly always a reason why a particular job requires attention. Some possible reasons are—

(1) The job in question is a new one not previously carried out (new product, component, operation or set of activities).

(2) A change in material or method of working has been made and a new time standard is required.

(3) A complaint has been received from a worker or workers' representative about the time standard for an operation.
Selecting the Job: Making a Time Study

(4) A particular operation appears to be a "bottleneck" holding up subsequent operations and possibly (through accumulations of work in process behind it) previous operations.

(5) Standard times are required prior to the introduction of an incentive scheme.

(6) To investigate the utilisation of a piece of plant the output of which is low, or which appears to be idle for an excessive time.

(7) As a preliminary to making a method study, or to compare the efficiency of two proposed methods.

(8) When the cost of a particular job appears to be excessive.

If the purpose of the study is the setting of performance standards it should not normally be undertaken until method study has been used to establish and define the most satisfactory way of doing the job. The reason for this is obvious: if the best method has not been discovered by systematic study, there is always the possibility that a much better way of doing it may be evolved either by the worker himself or by technical staff; a way which may need considerably less work to achieve the results required. The amount and nature of the reduction in work may vary at different times, according to which worker happens to be doing the job and the method he chooses to employ. The quantity of work involved in the process or operation may actually increase, if an operative less skilled than the one originally timed does the job later on and uses a method more laborious than that on the basis of which the time was set.

Until the best method has been developed, defined and standardised the amount of work which the job or process involves will not be stable. Planning of programmes will be thrown out, and, if the time standard is used for incentive purposes, the payment made to the operative may become uneconomic for the job. The worker may find the time unattainable, or, in the opposite case, may find that it is possible to complete the work in a much shorter time than that set as the standard. If so, he will very probably restrict his output to the maximum which he thinks the management will tolerate without starting to make inquiries into the validity of the time standard which has been set. Although in collective agreements introducing work study it is customary to include a clause permitting the retiming of jobs when the work content is altered in either direction, and management would, in theory, be justified in invoking this clause where a reduction in work content has been made, whether by worker or management, the retiming of jobs in such circumstances always tends to cause resentment, and if done a great deal will quickly shatter the confidence of the workers in both the competence of the work study staff and the honesty of the management. Therefore make sure the method is right, first. Remember, too, that any one time should refer only to one specified method.
Selecting the Job: Making a Time Study

There are problems in the selection of jobs to be studied which have nothing to do with the importance of the jobs to the enterprise or the abilities of the operators. A difficult one which may arise in factories where a piecework system is already in operation is that the existing piecework times on certain jobs, fixed by bargaining or estimation, may be so liberal that the workers have been earning high bonuses which cannot possibly be maintained if the jobs are properly reassessed. Attempts to alter the methods, which should automatically bring about a reassessment of the times allowed, may meet with such resistance that it is unwise to proceed with the studies. If this is the case, it is better, in an initial application, to tackle a number of jobs where it is evident that the earnings of the workers can be increased by the application of time study, even though these jobs may be less important to the performance of the shop as a whole. It may then be possible to return to the "problem" jobs when the rest of the shop has been studied and confidence in the integrity of the work study man has been established. It will almost certainly be necessary to negotiate on these problem jobs with the workers' representatives and it may be necessary to compensate the workers concerned. It is nevertheless possible to carry through such negotiations successfully if the purpose of the change is fully understood by all concerned.

2. THE APPROACH TO THE WORKER

The question of relationships between the work study man and the supervisors and workers in the enterprise was dealt with at some length in Chapter 5. The reason for mentioning it here is that what was said about work study in general applies with even more force to time study, especially with respect to the workers.

The purpose of a method study is usually obvious to everyone: it is to improve the method of doing the job, and everyone can see that it is a proper activity for the work study man to engage in. His efforts may even be welcomed by operatives if he succeeds in relieving them of fatiguing or unpleasant work. The purpose of a time study is less obvious, and unless it is very carefully explained to everyone concerned its object may be completely misunderstood or misrepresented, with consequent unrest and even strikes.

It is assumed that the work study man has already become a familiar figure in the shop while making method studies and that he is well known to the foreman and the workers' representatives. Nevertheless, if no time studies have previously been made there, he should first get the workers’ representatives and supervisors together and explain in simple terms what he is going to do and why, and should invite them to handle the watch. All questions should be answered frankly. This is where the value of work study courses for workers’ representatives and foremen shows itself.

If a choice of workers is available, it is good policy to ask the foreman and workers’ representatives to suggest the one most suitable to be studied first, emphasising that he should be a competent, steady person. His rate of working should
be average or slightly better than average. Some people are not temperamentally suited to being studied and cannot work normally while being watched. They should be avoided at all costs.

It is important, where the job is one likely to be done on a large scale—possibly by a large number of workers—to take studies on a number of qualified workers.

A distinction is made in time study practice between what are termed representative workers and qualified workers. A representative worker is one whose skill and performance is the average of the group under consideration. He is not necessarily a qualified worker. The concept of the qualified worker is an important one in time study. He is defined as follows:

A qualified worker is one who is accepted as having the necessary physical attributes, who possesses the required intelligence and education, and has acquired the necessary skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity and quality.

There is a reason for this insistence on selecting qualified workers. In setting time standards, especially when they are to be used for incentives, the standard to be aimed at is one which can be attained by the qualified worker, and which can be maintained without causing him undue fatigue. Because workers work at different speeds, observed times have to be adjusted by factors to give such a standard. These factors are dependent on the judgment of the studyman. Experience has shown that accuracy of judgment is only attainable within a fairly narrow range of speeds round about that which is normal for a qualified worker. The study of slow or unskilled workers or of exceptionally fast workers will tend to result in the setting of time standards that are either unduly large (known as “loose” times), and hence uneconomic, or unduly short (known as “tight” times), in which case they are unfair to the worker and will probably be the subject of complaints later.

Once the worker whose work is to be studied first has been selected he should be approached in company with the foreman and the workers' representative. The purpose of the study and what is required should be carefully explained. The worker should be asked to work at his usual pace, taking whatever rest he is accustomed to take. He should be invited to explain any difficulties he may encounter. (This procedure becomes unnecessary once work study is firmly established and its purpose well understood. It should, however, be carried out with new workers, and new members of the work study staff should be introduced to supervisors and workers when they start studies.) It is important to impress on the supervisor that the worker is then to be left alone. Some workers are liable to
panic if one of their direct supervisors is standing over them. This is especially true in those countries where there still exists a strongly paternalistic or "master-and-servant" relationship between management and workers.

If a new method has been installed the worker must be allowed plenty of time to settle down before he is timed. The "learning curve" in figure 54 (page 205) shows that it takes quite a long time for an operator to become adapted and to reach his maximum steady speed. It may be necessary to allow a job to run for days or even weeks before it is ready to be timed for the purpose of setting standards, depending on the duration and intricacy of the operation. In the same way, the work done by new operatives should never be used for timing until they have grown thoroughly accustomed to their jobs.

The position in which the studyman stands in relation to the operator is important. He should be so placed that he can see everything the operator does (especially the movements of his hands), without interfering with his movements or distracting his attention. The studyman should not stand directly in front of him, nor should he stand so close to him that he has the feeling of "having someone standing over him"—a frequent complaint made against time study. The studyman's exact position will be determined by the type of operation being studied, but the position generally recommended is to one side of the operator, slightly to the rear and about 2 metres away. In this position the operator can see him by turning his head a little and they can speak should it be necessary to ask a question or explain some point in connection with the operation. The study board and watch should be held well up in line with the job, to make reading the watch and recording easy while maintaining continuous observation.

On no account should any attempt be made to time the operator without his knowledge, from a concealed position or with the watch in the pocket. It is dishonest and, in any case, someone is sure to see and the news will spread like wildfire. Work study should have nothing to hide.

It is equally important that the studyman should stand up while making his study. There is a tendency on the part of workers to regard themselves as having to do all the work while the studyman simply stands around and watches them. This will be increased if the latter settles himself into a comfortable position. He will quickly lose the workers' respect, which is his greatest asset. He should neither sit nor lean but should hold himself comfortably in a position which he can maintain, if necessary, over a long period. Time study demands intense concentration and alertness especially when timing very short "elements" or "cycles" (defined later in this chapter), and it is generally agreed that this is better attained when standing.

Most operatives will quickly settle down to their normal working pace, but nervous workers, especially women, have a tendency to work unnaturally fast, which will cause them to fumble and make errors. If this happens, the studyman should stop the study and have a chat with the operative to put him at his ease, or even leave him to settle down for a bit.
More difficult to cope with is the "clever" worker who sets out to "put one across" the studyman. This is most likely to occur where it is known that the time standard to be set will be used as a basis for an incentive. The operative will go unnaturally slowly or insert unnecessary movements in the hope of getting a "looser" (longer) time. Some workers, usually the young ones, may do so out of devilment in order to match their wits against those of the studyman. It is hard to blame them, because many industrial jobs are dull enough in all conscience, and the battle adds a little spice to life! Nevertheless, from the studyman's point of view they are a nuisance.

On repetition work it is generally easy to detect operatives who are deliberately working at a pace which is not natural to them because, if they are working naturally, there will be very little variation in the times of the different cycles once they have got going, whereas it is difficult for them to control their cycle times when they are not. When there are wide variations in successive cycle times, and these are not due to variations in the material being worked on or to the tools or machine (in which case the studyman should report the variations to the proper authorities), the differing cycle times must be due to action on the operator's part. If this is the case, the studyman should discontinue the study and see the shop foreman. As a matter of practical diplomacy it may be wiser not to report the operator for attempting to "pull his leg", but to ask the foreman to come and look at the job as it does not seem to be running quite right. This is the sort of human situation that must be dealt with according to its merits if the studyman is not going to risk making himself unnecessarily unpopular, and is one of the reasons why the personal qualities of the studyman listed in Chapter 5 are so essential.

When technical considerations have a considerable influence on the job being studied it may be much less easy to detect attempts to stretch the time of the job, unless the studyman himself is an expert in the process. This is specially so where craft skill is involved, as in some sheet-metal work, or turning and screw-cutting operations to fine tolerances and high finish on centre lathes, even where speeds and feeds have been specified by the process planning department. It is difficult to argue with a skilled craftsman if you are not one yourself! This is one of the reasons why it is so important to establish precisely the method and conditions of operation before attempting to time it. A really good method study before the job is timed simplifies immensely the task of setting time standards.

In the foregoing paragraphs some effort has been made to suggest some of the practical problems which the studyman will have to face in obtaining representative times, but there are many others which can be learned only in the hard school of experience, in the atmosphere of the workshop, among the men and women who work there. They cannot be translated into print. The human-hearted man will delight in them; the other sort should not become work study men!
3. THE STEPS IN MAKING A TIME STUDY

Once the work to be measured has been selected the making of a time study usually consists of the following eight steps (see also figure 55):

1. Obtaining and recording all the information available about the job, the operator and the surrounding conditions, which is likely to affect the carrying out of the work.

2. Recording a complete description of the method, breaking down the operation into "elements".

3. Examining the detailed breakdown to ensure that the most effective method and motions are being used.

4. Measuring with a timing device (usually a stopwatch) and recording the time taken by the operator to perform each "element" of the operation.

5. At the same time assessing the effective speed of the working of the operative in relation to the observer's concept of the rate corresponding to standard rating.

6. Extending the observed times to "basic times".

7. Determining the allowances to be made over and above the basic time for the operation.

8. Determining the "standard time" for the operation.


The following information (or those items which apply to the operation being studied) should be recorded from observation before starting the study proper. It is usual to do so on the time study top sheet. If the various headings are printed or stencilled it helps to ensure that no vital piece of information is overlooked. The exact number of the items listed below which may have to be included when designing a time study form will depend on the type of work carried out in the undertaking in which it is to be used. In non-manufacturing industries such as transport and catering it should not be necessary to include space for the "product", etc. Factories where all the work is manual will require space for "tools" but not for "plant or machine".

The filling in of all the relevant information from direct observation is important in case the time study has to be referred to later; incomplete information may make a study practically useless a few months after it has been made. The forms shown in figures 58 to 62 are designed for manufacturing industry to show the maximum amount of information usually necessary.
Selecting the Job: Making a Time Study

The information to be obtained may be grouped as follows:

A. **Information to enable the study to be found and identified quickly when needed.**

   Study number.
   Sheet number and number of sheets.
   Name or initials of the studyman making the study.
   Date of the study.
   Name of the person approving the study (head of the work study department, production manager or other appropriate executive).

B. **Information to enable the product or part being processed to be identified accurately.**

   Name of product or part.
   Drawing or specification number.
   Part number (if different from drawing number).
   Material.
   Quality requirements.¹

C. **Information to enable the process, method, plant or machine to be accurately identified.**

   Department or location where the operation is taking place.
   Description of the operation or activity.
   Method study or standard practice sheet numbers (where they exist).
   Plant or machine (maker's name, type size or capacity).
   Tools, jigs, fixtures and gauges used.
   Sketch of the workplace layout, machine set-up and/or part showing surfaces worked (on the reverse of the time study top sheet, or on a separate sheet attached to the study if necessary).
   Machine speeds and feeds or other setting information governing the rate of production of the machine or process (e.g. temperature, pressure, flow, etc.). It is good practice to have the foreman initial the study form alongside the record of information of this sort, as an endorsement of its correctness.

D. **Information to enable the operator to be identified.**

   Operator's name.
   Clock number.²

¹ In the case of some engineering products parts may be modified from time to time and the drawings reissued. It may, therefore, also be necessary to note the issue number.

² For “Quality Requirements” it may simply be sufficient to put a standard specification number or “Good Finish”. In engineering practice tolerances and finish are generally specified on the drawing.

² In cases where both men and women are likely to be employed on similar jobs it is desirable to note the sex of the operator. In the case of new jobs or new operators it may also be desirable to note the amount of experience the operator has had on the particular operation at the time of the study so that the point that they have reached on the learning curve (see figure 54) can be assessed.
E. Duration of the study.

The start of the study (Time On).
The finish of the study (Time Off).
Elapsed time.

F. Working conditions

Temperature, humidity, adequacy of the lighting, etc., in supplement to the information recorded on the sketch of the workplace layout.

5. CHECKING THE METHOD

Before proceeding with the study it is important to check the method being used by the operative. If the study is for the purpose of setting a time standard a method study should already have been made and a written standard practice sheet completed. In this case it is simply a question of comparing what is actually being done with what is specified on the sheet. If the study is being made as the result of a complaint from a worker that he is unable to attain the output set by a previous study, his method must be very carefully compared with that used when the original study was made. It will often be found in such cases that the operator is not carrying out the work as originally specified: he may be using different tools, a different machine set-up or different speeds and feeds, temperatures, rates of flow or whatever the requirements of the process may be, or additional work may have crept in.

It may be that the cutting tools are worn, or have been sharpened to incorrect profiles. Times obtained when observing work carried out with worn tools or incorrect process conditions should not be used for the compilation of time standards.

In highly repetitive short cycle work, such as work on a conveyor band (light assembly, packing biscuits, sorting tiles), changes in method may be much more difficult to detect, since they may involve changes in the movements of the arms and hands of the operator ("motion patterns") which can only be observed with difficulty by the naked eye and require special apparatus to analyse.

Although it has been emphasised repeatedly in this book that a proper method study should be made before a time study is undertaken for the purpose of setting time standards, there are occasions when time standards may have to be set without a full-scale method study beforehand. This is most likely to occur with short-run jobs which are only done a few times a year in the shop concerned. In such cases the studyman should make a careful record of the method by which the job is being done after putting right any obvious inefficiencies—in organisation, for instance, by providing containers for finished work in the proper positions or by checking machine speeds. This record becomes specially important as it will be the only record available, and changes in methods will be more likely to occur where operators have not been instructed in one definite method.
6. BREAKING THE JOB INTO ELEMENTS

Once the studyman has recorded all the information about the operation and the operator needed for proper identification in the future and has satisfied himself that the method being used is the correct one or the best possible in the prevailing circumstances he must start to break it down into elements.

**An element is a distinct part of a specified job selected for convenience of observation, measurement and analysis.**

**A work cycle is the sequence of elements which are required to perform a job or yield a unit of production. The sequence may sometimes include occasional elements.**

A work cycle starts at the beginning of the first element of the operation or activity and continues to the same point in a repetition of the operation or activity. That is the start of the second cycle. This is illustrated in the fully worked-out example of a time study in Chapter 19.

A detailed breakdown into elements is necessary—

1. To ensure that productive work (or effective time) is separated from unproductive activity (or ineffective time).

2. To permit the rate of working to be assessed more accurately than would be possible if the assessment were made over a complete cycle. The operative may not work at the same pace throughout the cycle, and may tend to perform some elements faster than others.

3. To enable the different types of element (see below) to be identified and distinguished, so that each may be accorded the treatment appropriate to its type.

4. To enable elements involving high fatigue to be isolated and to make the allocation of fatigue allowances more accurate.

5. To facilitate checking the method and so that the subsequent omission or insertion of elements may be detected quickly. This may become necessary if at a future date the time standard for the job is queried.

6. To enable a detailed work specification (see Chapter 20) to be produced.
(7) To enable time values for frequently recurring elements, such as the operation of machine controls or loading and unloading workpieces from fixtures, to be extracted and used in the compilation of synthetic data (see Chapter 21).

Types of Element

Eight types of element are distinguished: repetitive, occasional, constant, variable, manual, machine, governing, and foreign elements. The definition of each, as given in the British Standard Glossary of Terms in Work Study, is listed below, together with examples—

- A repetitive element is an element which occurs in every work cycle of the job.

  Examples: the element of picking up a part prior to an assembly operation; the element of locating a workpiece in a holding device; putting aside a finished component or assembly.

- An occasional element is an element which does not occur in every work cycle of the job, but which may occur at regular or irregular intervals.

  Examples: clearing swarf; adjusting the tension, or machine setting; receiving instructions from the foreman. The occasional element is useful work and a part of the job. It will be incorporated in the final standard time for the job.

- A constant element is an element for which the basic time remains constant whenever it is performed.

  Examples: switch on machine; gauge diameter; screw on and tighten nut; insert a particular cutting tool into machine.

- A variable element is an element for which the basic time varies in relation to some characteristics of the product, equipment or process, e.g. dimensions, weight, quality, etc.

  Examples: saw logs with handsaw (time varies with hardness and diameter); sweep floor (varies with area); push trolley of parts to next shop (varies with distance).

- A manual element is an element performed by a worker.

- A machine element is an element automatically performed by a power-driven machine (or process).

  Examples: anneal tubes, fire tiles; form glass bottles; press car body shell to shape; most actual cutting elements on machine tools.
Selecting the Job: Making a Time Study

- A **governing element** is an element occupying a longer time than that of any other element which is being performed concurrently.

  Examples: turn diameter on a lathe, while gauging from time to time; boil kettle of water, while setting out teapot and cups; develop photographic negative, while agitating the solution occasionally.

- A **foreign element** is an element observed during a study which, after analysis, is not found to be a necessary part of the job.

  Examples: in furniture manufacture, sanding the edge of a board before planing has been completed; degreasing a part that has still to be machined further.

It will be clear from the definitions given above that a repetitive element may also be a constant element, or a variable one. Similarly, a constant element may also be repetitive or occasional; an occasional element may be constant or variable, and so on, for the categories are not mutually exclusive.

7. DECIDING THE ELEMENTS

There are some general rules concerning the way in which a job should be broken down into elements. They include the following:

Elements should be easily identifiable, with definite beginnings and endings so that, once established, they can be repeatedly recognised. These beginnings and endings can often be recognised by a sound (e.g. the stopping of a machine, unlocking a catch of a jig, putting down a tool) or by a change of direction of hand or arm. They are known as the "break points" and should be clearly described on the study sheet. A break point is thus the instant at which one element in a work cycle ends and another begins.

Elements should be as short as can be conveniently timed by a trained observer. Opinion differs on the smallest practical unit that can be timed with a stopwatch, but it is generally considered to be about 0.04 min (2.4 sec). For less highly trained observers it may be 0.07 to 0.10 min. Very short elements should, if possible, be next to longer elements for accurate timing and recording. Long manual elements should be rated about every 0.33 min (20 sec).

As far as possible, elements—particularly manual ones—should be chosen so that they represent naturally unified and recognisably distinct segments of the operation. For example, consider the action

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2 Rating is described and discussed in the next chapter.
Selecting the Job: Making a Time Study

of reaching for a wrench, moving it to the work and positioning it to tighten a nut. It is possible to identify the actions of reaching, grasping, moving to the workpiece, shifting the wrench in the hand to the position giving the best grip for turning it, and positioning. The worker will probably perform all these as one natural set of motions rather than as a series of independent acts. It is better to treat the group as a whole, defining the element as “get wrench” or “get and position wrench” and to time the whole set of motions which make up the group, than to select a break point at, say, the instant the fingers first touch the wrench, which would result in the natural group of motions being divided between two elements.

Manual elements should be separated from machine elements. Machine time with automatic feeds or fixed speeds can be calculated and used as a check on the stopwatch data. Hand time is normally completely within the control of the operator. This separation is specially important if standard times are being compiled.

Constant elements should be separated from variable elements.

Elements which do not occur in every cycle (i.e. occasional and foreign elements) should be timed separately from those that do.

The necessity for a fine breakdown of elements depends largely on the type of manufacturing, the nature of the operation and the results desired. Assembly operations in the light electrical and radio industries, for example, generally have short cycle operations with very short elements.

The importance of proper selection, definition and description of elements must again be emphasised. The amount of detail in the description will depend on a number of factors, for instance—

- Small batch jobs which occur infrequently require less detailed element descriptions than long-running, high-output lines.
- Movement from place to place generally requires less description than hand and arm movements.

Elements should be checked through a number of cycles and written down before timing begins.

Examples of element descriptions and of various types of element are shown in figures 78 and 80.

8. TIMING EACH ELEMENT: STOPWATCH PROCEDURE

Once the elements have been selected and written down, timing can start.
There are two principal methods of timing with the stopwatch:

- Cumulative timing;
- Flyback timing.

In cumulative timing the watch runs continuously throughout the study. It is started at the beginning of the first element of the first cycle to be timed and is not stopped until the whole study is completed. At the end of each element the watch reading is recorded. The individual element times are obtained by successive subtractions after the study is completed. The purpose of this procedure is to ensure that all the time during which the job is observed is recorded in the study.

In flyback timing the hands of the stopwatch are returned to zero at the end of each element and are allowed to start immediately, the time for each element being obtained directly. The mechanism of the watch is never stopped and the hand immediately starts to record the time of the next element.

In all time studies it is usual to take an independent check of the over-all time of the study using either a wrist watch, or the clock in the study office. This also serves the purpose of noting the time of day at which the study was taken, which may be important if a retiming is asked for. For example, the cycle time of an operative on a repetitive job may be shorter in the first hour or two of the morning, when he is fresh, than late in the afternoon, when he is tired.

In the case of flyback timing the studyman walks to the clock and at an exact minute, preferably at the next major division such as the hour or one of the five-minute points, starts his stopwatch running, noting the exact time in the "time on" space on the form. He returns to the workplace where he is going to carry out the time study with the watch running and allows it to do so continuously until he is ready to start timing. At the beginning of the first element of the first work cycle he snaps back the hand, noting, as the first entry on the body of his study sheet, the time that has elapsed. At the end of the study the hand is snapped back to zero on completion of the last element of the last cycle and thereafter allowed to run continuously until he can again reach the clock and note the time of finishing, when the watch is finally stopped. The final clock time is entered in the "time off" space on the form. The two times recorded before and after the study are known as "check times". The clock reading at the beginning of the study is subtracted from the clock reading at the end of the study to give the "elapsed time", which is entered on the form.

The sum of the times of all the elements and other activities noted in the study plus ineffective time plus the check times is known as the "recorded time" and is also noted. It should in theory agree with the elapsed time, but in practice there is usually a small difference owing to the cumulative loss of very small fractions of time at the return of the hand to zero and, possibly, bad reading or missed elements. In certain firms in the United Kingdom it is the practice to discard any study in which the elapsed time differs from the recorded time by more than ± 2 per cent.
When the same practice is followed using cumulative timing the elapsed time and recorded time should be identical since the stopwatch is only read and not snapped back.

Cumulative timing has the advantage that even if an element is missed or some occasional activity not recorded, this will have no effect on the over-all time. It is strongly favoured by many trade unions, especially in the United States, since it is regarded by them as more accurate than flyback timing and gives no opportunity for altering times in favour of management by omitting elements or other activities. Its disadvantage is, of course, the amount of subtraction which has to be done to arrive at individual element times, which greatly increases the time taken in working up the study afterwards.

Flyback timing is still widely used in the United States, in Great Britain and on the continent of Europe. In competent hands it is practically as accurate as continuous timing. Mundel quotes some comparative tests of the two methods carried out by Lazarus at the Purdue University Motion and Time Study Laboratory with a number of experienced time study observers in which the average error in reading the watch using the cumulative method was $+0.000097$ min per reading and using the flyback method was $-0.00082$ min per reading. Errors of this order are not large enough to influence subsequent calculations. It should be noted, however, that these very small average errors were made by experienced observers. There is reason to suppose that people being trained in the use of the stopwatch attain a fair degree of accuracy more quickly when using the cumulative method than when using the flyback method.

The experience of I.L.O. missions in teaching and applying time study has in fact shown that, generally speaking, cumulative timing should be taught and used, for the following reasons:

1. Experience suggests that trainees achieve reasonable accuracy in the use of the stopwatch more quickly using the cumulative method.

2. It does not matter if element times are occasionally missed by inexperienced observers; the over-all time of the study will not be affected. Foreign elements and interruptions are automatically included since the watch is never stopped.

3. In assessing the working pace of the operator ("rating") it is less easy to fall into the temptation to adjust the rating to the time taken by the element than with the flyback method, since only watch readings and not actual times are recorded.

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Workers and their representatives are likely to have greater faith in the fairness of time studies as a basis for incentive plans if they can see that no time can have been omitted. The introduction of time study into an undertaking or an industry may be made easier.

In the flyback method, errors in reading the watch may be added to the slight delay which occurs when the hand is snapped back to zero. The percentage error becomes greater for short elements. Continuous timing is therefore likely to be more accurate for short-element short-cycle work, while flyback timing can be more safely used in jobs with long elements and cycles, since the error becomes too small to matter. The question of the confidence of the workers is important as well.

There is a third method of timing which is employed for short-element short-cycle work, and which may indeed be the only way of getting accurate times with a stopwatch, for elements which are so very short that there is not enough time for the studyman to read his watch and make a recording on his study sheet. In this situation the method used is that known as differential timing. With differential timing, elements are timed in groups, first including and then excluding each small element, the time for each element being obtained subsequently by subtraction. For example, if the job consists of seven short elements, the studyman may time numbers 1 to 3, and 4 to 7 for the first few cycles, recording only these two readings per cycle. He would then time 1 to 4 and 5 to 7 for a few cycles; and so on. If differential timing is applied in this fashion either the cumulative or the flyback method of watch manipulation may be used.

9. HOW MANY CYCLES SHOULD BE TIMED?

Time study is a sampling technique, and, as in all sampling, the accuracy with which the final values obtained represent the true time values for the elements of an operation and the total time for the operation itself will depend to some extent on the size of the sample. Certain general principles govern the number of cycles to be observed to obtain a reasonably representative time for any particular operation. These are as follows:

1. It would be unusual for a standard time to be compiled from the recordings made during a single study, for not only is it desirable to observe the operation as carried out by different workers but it may often be necessary to make studies at different times during the day, or on different shifts, to ensure that any variation in the working conditions is fully taken into account.

2. The number of cycles through which any particular job should be observed varies directly as the amount of variation in the times of the elements of the job. Jobs in which there are variations in material from piece to piece, difficulties in locating workpieces accurately in
fixtures, fineness of finish or close tolerances have to be observed through a greater number of cycles than those carried out in standard conditions.

(3) The number of cycles to be observed will depend on the degree of accuracy desired. This in turn will depend on the length of run of the job and the number of people engaged on it. If a job is going to run day in and day out for years and affect a large number of operatives it is obviously desirable to obtain a very accurate time value for it. If the job is one which comes into a shop only occasionally and affects only one operator it is not necessary or economic to attempt to achieve very great accuracy.\(^1\)

(4) The studies should be continued through a sufficient number of cycles to ensure that occasional elements such as handling boxes of finished parts, periodical cleaning of machines or workplaces, or sharpening tools can be observed several times.

(5) Where more than one operative is engaged on the same job it is preferable to make short studies (say ten cycles) of the work of each of several operatives rather than one long one on a single worker.

The studies should continue for as many cycles as the studyman considers necessary to obtain a satisfactory picture of what is happening. Where there is a lot of variation in element times not completely under the control of the operator a long series of studies may be necessary. In general at least 50 cycles of short cycle operations and at least 20 or 30 cycles of longer cycle work should be observed. However, these figures are only a guide; if after several studies and analysis of the element times there are still doubts in the mind of the studyman on the validity of his figures he should make further studies, if possible on the work of other operatives.

Variability in element times is referred to again in Chapter 17 during the description of study analysis. A simple method of watching how the study work is progressing, by plotting progressive average element times until the graph exhibits repeating basic times—indicating that enough studies have been taken—is set out there.

We have now discussed all the preliminaries to making a time study, from the selection of the job through the recording of all relevant data, the breakdown of the job into elements, examination of the methods employed, to the recording of the actual element times. In the next chapter the means of modifying these observed times to take into account variations in rates of working will be discussed.

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\(^1\) For a detailed discussion of ways of determining the number of readings to be taken see G. NADLER, op.cit., pp. 370-378.
In section 3 of the last chapter the making of a time study was broken down into seven steps or stages, the first three of which were discussed in that chapter. We now come to the fourth step, namely “assessing the effective speed of working of the operative relative to the observer's concept of the rate corresponding to standard rating”.

The treatment of rating which follows has been selected because experience in the use of this manual by I.L.O. management and productivity missions for teaching purposes suggests that this approach to the subject is best suited to the conditions in most countries for which the book is primarily intended.

Rating and “allowances” (dealt with in the next chapter) are the two most controversial aspects of time study. Most time studies in industry are used to determine standard times for setting workloads and as a basis for incentive plans.
The procedures employed have a bearing upon the earnings of the workers as well as the productivity and, possibly, the profits of the enterprise. Time study is not an exact science, although much research has been undertaken, mainly in the United States, to attempt to establish a scientific basis for it. Rating (the assessment of a worker's rate of working) and the allowances to be given for recovery from fatigue and other purposes are still, however, largely matters of judgment and therefore of bargaining between management and labour.

Various methods of assessing the rate of working, each of which has its good and bad points, have been developed. The procedures set out in this chapter represent sound current practice and, properly applied, should be acceptable to management and workers alike, particularly when used to determine standards for medium-batch production, which is the type most general in industry all over the world outside the United States and a few large or specialised undertakings elsewhere. They will certainly provide the reader with a sound basic system which will serve him well for most general applications, and one which can later be refined if the particular nature of certain special operations demands a modification of the system, so as to rate something other than effective speed.

1. THE QUALIFIED WORKER

It has already been said that time studies should be made, as far as possible, on a number of qualified workers; also, that very fast or very slow workers should be avoided, at least while making the first few studies of an operation. What is a "qualified worker"?

Different jobs require different human abilities. For example, some demand mental alertness, concentration, visual acuity; others physical strength; most, some acquired skill or special knowledge. Not all workers will have the abilities required to perform a particular job, though if the management makes use of sound selection procedures and job training programmes it should normally be possible to arrange that most of the workers engaged on it have the attributes needed to fit them for the task. The definition of a qualified worker given in the last chapter is repeated here—

A qualified worker is one who is accepted as having the necessary physical attributes, who possesses the required intelligence and education, and has acquired the necessary skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity and quality.
The acquisition of skill is a complicated process. It has been observed\(^1\) that among the attributes which differentiate the experienced worker from the inexperienced are the following. The experienced worker—

- achieves smooth and consistent movements;
- acquires rhythm;
- responds more rapidly to signals;
- anticipates difficulties and is more ready to overcome them;
- carries out the task without giving the appearance of conscious attention, and is therefore more relaxed.

It may take a good deal of time to become fully skilled in the performance of a job. In one study\(^2\) it was noted that it was only after some 8,000 cycles of practice that the times taken by workers began to approach a constant figure—which was itself half the time they took when they first essayed the operation. Thus time standards set on the basis of the rate of working of inexperienced workers could turn out to be quite badly wrong, if the job is one with a long learning period. Some jobs, of course, can be learned very quickly.

It would be ideal if the time study man could be sure that, whatever job he selected for study, he would find only properly qualified workers performing it. In practice this is too much to hope for. It may indeed be that none of the workers engaged on the task can really be said to be completely qualified to carry it out, though it may be possible to alter this in time, by training. Or that, though some of the workers are qualified, these are so few in number that they cannot be considered to be average or representative of the group. A representative worker is defined as one whose skill and performance is the average of a group under consideration. He is not necessarily a qualified worker.

If the working group is made up wholly or mainly of qualified workers then there will be one—or perhaps several—of these qualified workers who can be considered as representative workers also. The concept of a standard time is, at root, that it is a time for a job or operation that should normally be attainable by the average qualified worker, working in his ordinary fashion, provided that he is sufficiently motivated to want to get on with the job. In theory, therefore, the time study man should be looking for the average qualified worker to study. In practice this is not as easy as it might seem. It is worth looking more closely into what "average" might mean in this context.

\(^2\) See figure 54, p. 205.
2. THE “AVERAGE” WORKER

The truly average worker is no more than an idea. A completely average worker does not exist any more than does an “average family” or an “average man”. They are the inventions of statisticians. We are all individuals, no two of us are exactly alike. Nevertheless, among a large number of people from, for instance, the same country or area variations in measurable characteristics such as height and weight tend to form a pattern which, when represented graphically, is called the “normal distribution curve”. To take one characteristic, height: in many western European countries the average height for a man is about 5 ft. 8 in. (172 cm). If a crowd is a western European crowd, a large number of the men in it will be between 5 ft. 7 in. and 5 ft. 9 in. tall (170–175 cm). The number of men of heights greater or smaller than this will become fewer and fewer as those heights approach the extremes of tallness and shortness.

Exactly the same is the case with the performance of operatives. This can be shown very conveniently in a diagram (figure 65). If 500 qualified workers in a given factory were to do the same operation by the same methods and under the same conditions, the whole operation being within the control of the worker himself, then the times taken to perform the operation would be distributed in the manner shown in the figure. To simplify the figure the times have been divided into groups at intervals of four seconds. It will be seen that the workers fall into the following groupings:

<table>
<thead>
<tr>
<th>TABLE 10. SPECIMEN PERFORMANCE DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time group (sec)</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>30–34</td>
</tr>
<tr>
<td>34–38</td>
</tr>
<tr>
<td>38–42</td>
</tr>
<tr>
<td>42–46</td>
</tr>
<tr>
<td>46–50</td>
</tr>
<tr>
<td>50–54</td>
</tr>
<tr>
<td>54–58</td>
</tr>
<tr>
<td>58–62</td>
</tr>
<tr>
<td>62–66</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

If the time groups are examined it will be seen that 32.4 per cent. of the times are less than 46 sec and 34.8 per cent. of the times are greater than 50 sec. The largest single group of times (32.8 per cent.) lies between 46 and 50 sec. We should therefore be justified in saying that for this group of 500 workers the average time taken to perform this operation was between 46 and 50 sec (say 48 sec). We could call 48 sec the time taken by the average qualified worker to do this job.
FIGURE 65. DISTRIBUTION OF TIMES TAKEN BY WORKERS TO PERFORM A GIVEN JOB

- Normal curve of distribution
- Number of workers:
  - 4 (0.8%)
  - 16 (3.2%)
  - 38 (7.6%)
  - 104 (20.8%)
  - 113 (22.6%)
  - 48 (9.6%)
  - 11 (2.2%)
  - 2 (0.4%)

Time Study: Rating

Percentage

Number of workers

Seconds
Time Study: Rating

under these conditions. The time might not hold good for any other factory. Factories which are well run, where working conditions and pay are good, tend to attract and keep the best workers so that, in a better run factory, the average worker's time might be less (say 44 sec) while in a poorly run factory with less able workers it might be more (say 52 sec).

If a curve is drawn to fit this distribution it will be found to assume the shape of the curve in the figure. This is known as the "normal distribution curve". In general, the larger the sample the more the curve will tend to be symmetrical about the peak value but this can be altered if special conditions are introduced. For example, if the slower workers were to be transferred to other work the right-hand side of the curve of performances of the group would probably become foreshortened, for there would be fewer workers returning the very long times.

3. STANDARD RATING AND STANDARD PERFORMANCE

In Chapter 13, Section 3, it was said that the principal use of work measurement (and hence of time study) was to set time standards which could be used for a number of different purposes (including programme planning, estimating, and as a basis for incentives) for the various jobs carried out in the undertaking. Obviously, if those time standards are to be of any value at all their achievement must be within the capacity of the majority of workers in the enterprise. It would be no use setting standards so high that only the best could attain them, since programmes or estimates based on them would never be fulfilled. Equally, to set standards well within the achievement of the slowest workers would not be conducive to efficiency.

How does the work study man obtain such a fair time from time studies?

We have already said that, as far as possible, studies should be taken on qualified workers. If it were possible to obtain the times taken by 500 qualified operatives for a single operation and plot them in the manner shown in figure 65 a reliable average time would be obtained. Unfortunately this is hardly ever possible. It is not always possible to time a job on an average qualified worker; moreover, even if it were, people do not work consistently from day to day or even from minute to minute. The work study man has to have some means of assessing the rate of working of the operator he is observing and relating it to standard pace. The process of doing this is known as rating.

**Rating is the assessment of the worker's rate of working relative to the observer's concept of the rate corresponding to standard pace.**

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1 For details of various well-known types of incentive plans see I.L.O.: *Payment by Results*, Studies and Reports, New Series, No. 27 (Geneva, 9th impression, 1967).

2 The definition given in the *British Standard Glossary of Terms in Work Study* concludes with the words "standard rating", rather than "standard pace", as used here. It is considered that the word "pace" more exactly conveys the sense of a rate of working than "rating", which has connotations implying a factor, or ratio, which do not help clarity at this point in the explanation.
By definition, rating is a comparison of the rate of working observed by the work study man with a picture of some standard level which he is holding in his mind. This standard level is the average rate at which qualified workers will naturally work at a job, when using the correct method and when motivated to apply themselves to their work. This rate of working corresponds to what is termed the **standard rating**, and is denoted by 100 on the rating scale recommended to readers of this book (see Section 7 below). If the standard pace is maintained and the appropriate relaxation is taken, a worker will achieve **standard performance** over the working day or shift.

**Standard performance is the rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift provided they know and adhere to the specified method and provided they are motivated to apply themselves to their work.**

**This performance is denoted as 100 on the standard rating and performance scales.**

The rate of working most generally accepted in the United States and Great Britain as corresponding to the standard rating is equivalent to the speed of motion of the limbs of a man of average physique walking without a load in a straight line on level ground at a speed of 4 miles an hour (6.4 kilometres per hour). This is a brisk, businesslike rate of walking, which a man of the right physique and well accustomed to walking might be expected to maintain, provided he took appropriate rest pauses every so often. This pace has been selected as a result of long experience as providing a suitable benchmark to correspond to a rate of working which would enable the average qualified worker who is prepared to apply himself to his task to earn a fair bonus by working at that rate, without there being any risk of imposing on him any undue strain which would affect his health, even over a long period of time. (As a matter of interest, a man walking at 4 miles an hour (6.4 km/h) appears to be moving with some purpose or destination in mind: he is not sauntering, but on the other hand he is not hurrying. Men hurrying, to catch a train for instance, often walk at a considerably faster pace before breaking out into a trot or a run, but it is a pace which they would not wish to keep up for very long.)

It should be noted however that the “standard pace” applies to Europeans and North Americans working in temperate conditions; it may not be a proper pace to consider standard in other parts of the world. In general, however, given workers of proper physique, adequately nourished, fully trained and suitably motivated, there seems little evidence to suggest that different standards for rates of working are needed in different localities, though the periods of time over which
Time Study: Rating

workers may be expected to average the standard pace will vary very widely with the environmental conditions. At the very least, the standard rate as described above provides a theoretical datum line with which comparisons of performance in different parts of the world could be made in order to determine whether any adjustment may be necessary. Another accepted example of working at the standard rate is dealing a pack of 52 playing cards in 0.375 min.

**FIGURE 66. THE EFFECT OF INEFFECTIVE TIME ON PERFORMANCE**

<table>
<thead>
<tr>
<th>Worker A</th>
<th>Worker B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 15 min 30 min 45 min 1 h</td>
<td>0 15 min 30 min 45 min 1 h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work done in one hour by A</th>
<th>Work done in one hour by B</th>
</tr>
</thead>
</table>

Standard performance on the part of the average qualified worker, that is one with sufficient intelligence and physique, adequately trained and experienced in the job he is doing, will probably only show as such over several hours. Anyone doing manual work will generally carry out the motions directly concerned with his work at his own natural working rate, which may not be exactly the standard rate, since some men work faster than others. There will of course be different standard paces (or speeds of movement) for different activities, according to the complexity or arduousness of the element making up the activity (among other things), so that working at the standard rate will not always mean moving the hands or limbs with the same speed. And in any event, it is not uncommon for workers to work faster at some periods of the day than they do during others, so that the standard performance is rarely achieved as the result of working without any deviation at the standard rate throughout the working periods of the shift, but rather as the cumulative outcome of periods of work at varying paces.

When time standards are used as a basis for payment by results many union-management agreements stipulate that the time standards should be such that a representative or average qualified worker on incentive pay can earn 20-35 per cent. above his time rate by achieving the standard performance. If the worker has no target to aim at and no incentive to make him desire a higher output he will, apart
from any time he may waste consciously, tolerate the intrusion of small pieces of ineffective time, often seconds or fractions of seconds between and within elements of work. In this way he may easily reduce his performance over an hour or so to a level much below that of the standard performance. If, however, he is given enough incentive to make him want to increase his output he will get rid of these small periods of ineffective time, and the gaps between his productive movements will narrow. This may also alter the pattern of his movements.¹ The effect of the elimination of these small periods of ineffective time under the influence of an incentive can be illustrated diagrammatically (see figure 66).

What happens may be seen in the case of a man working a lathe who has to gauge his workpiece from time to time. His gauge is laid on the tool locker beside him. If he has no particular reason to hurry he may turn his whole body round every time he wishes to pick up the gauge, turn back to the lathe, gauge the workpiece and turn again to put the gauge down, each of these movements being carried out at his natural pace. As soon as he has reason to speed up his rate of working, instead of turning his whole body he will merely stretch out his arm, perhaps glancing round to check the position of the gauge on the locker, pick up the gauge, gauge the workpiece and replace the gauge on the locker with a movement of his arm, without bothering to look. In neither case would there be a deliberate stopping of work, but in the second some movements—ineffective from the point of view of furthering the operation—would have been eliminated.

The effect of putting a whole shop or factory (such as the 500 workers in figure 65) on an incentive is shown in figure 67.

† Research carried out under the late Professor T. U. Matthew at the University of Birmingham (England) tended to confirm this.
Offering an incentive in the form of payment in proportion to output will not make the unskilled or slow worker as fast or as skilled as the skilled or naturally fast worker, but if everyone in the shop is put on a well-designed incentive plan, other conditions remaining the same, the result will be that everyone will tend to work more consistently. The little periods of ineffective time discussed above will disappear, and everyone’s average time for the job will be reduced. (This is an over-simplification but true enough for purposes of illustration.) The normal distribution curve shown in figure 65 will move to the left while retaining approximately the same shape. This is quite clearly shown in figure 67, where the peak of the curve (the average time) now comes at 36 sec instead of 48—a reduction of 25 per cent.

It remains to be added that although the standard rate of working is that at which the average qualified worker will naturally perform his movements when motivated to apply himself to his task, it is of course quite possible and indeed normal for him to exceed this rate of working if he wishes to do so, just as a man can walk faster than 4 miles an hour if he wants to. Men will be observed to be working, sometimes faster, sometimes slower than the standard rate, during short periods. Standard performance is achieved by working over the shift at paces which average the standard rate.

4. COMPARING THE OBSERVED RATE OF WORKING WITH THE STANDARD

How is it possible accurately to compare the observed rate of working with the theoretical standard? By long practice.

To revert once more to our man walking: most people, if asked, would be able to judge the rate at which a man is walking. They would start classifying rates of walking as slow, average or fast. With a little practice they would be able to say: “About 3 miles an hour, about 4 miles an hour, or about 5 miles an hour” (or of course the equivalent rates in kilometres if they are more used to kilometres). If, however, a reasonably intelligent person were to spend all his time watching men walking at different speeds he would soon reach the point where he could say: “That man is walking at 2 ½ miles an hour and this one at 4 ¼ miles an hour”, and he would be right, within close limits. In order to achieve such accuracy, however, he would need to have in his mind some particular rate with which to compare those which he sees.

That is exactly what the work study man does in rating, but, since the operations which he has to observe are far more complex than the simple one of walking without load, his training takes very much longer. Judgment of walking pace is only used for training work study men in the first stages; it bears very little resemblance to most of the jobs that have to be rated. It has been found better to use films or live demonstrations of industrial operations.
Confidence in the accuracy of one's rating can only be acquired through long experience and practice on many types of operation—and confidence is essential to a work study man. It may be necessary for him to back his judgment in arguments with management, foremen or workers' representatives; unless he can do so with assurance the confidence of all parties in his ability will quickly disappear, and he might as well give up practising time study. This is one of the reasons why trainees may attempt method study after a comparatively short training but should on no account try to set time standards—except under expert guidance—without long practice, especially if the standards are to be used for incentive payments.

5. WHAT IS RATED?

The purpose of rating is to determine from the time actually taken by the operator being observed the standard time which can be maintained by the average qualified worker and which can be used as a realistic basis for planning, control and incentive schemes. What the studyman is concerned with is therefore the speed with which the operator carries out the work, in relation to the studyman’s concept of a normal speed. In fact, speed of working as recorded by the time taken to carry out the elements of the operation is the only thing which can be measured with a stopwatch. Most authorities on time study agree on this point.

Speed of what? Certainly not merely speed of movement, because an unskilled operator may move extremely fast and yet take longer to perform an operation than a skilled operator who appears to be working quite slowly. The unskilled operator puts in a lot of unnecessary movements which the experienced operator has long since eliminated. The only thing that counts is the effective speed of the operation. Judgment of effective speed can only be acquired through experience and knowledge of the operations being observed. It is very easy for an inexperienced studyman either to be fooled by a large number of rapid movements into believing that an operator is working at a high rate or to underestimate the rate of working of the skilled operator whose apparently slow movements are very economical of motion.

A constant source of discussion in time study is the rating of effort. Should effort be rated, and if so, how? The problem arises as soon as it becomes necessary to study jobs other than very light work where little muscular effort is required. Effort is very difficult to rate. The result of exerting effort is usually only seen in the speed.

The amount of effort which has to be exerted and the difficulty encountered by the operator is a matter for the studyman to judge in the light of his experience with the type of job. For example, if an operator has to lift a heavy mould from the filling table, carry it across the shop and put it on the ground near the ladle, only experience will tell the observer whether he is doing it at a normal, above- or sub-normal speed. Anyone who had never studied operations involving carrying heavy weights would have great difficulty in making an assessment the first time he saw it.
Operations involving mental activities (judgment of finish, for example, in inspection of work) are most difficult to assess. Experience of the type of work is required before satisfactory assessments can be made. Inexperienced studymen can be made to look very foolish in such cases and equally can be unjust to above-average and conscientious workers.

In any job the speed of accomplishment must be related to an idea of a normal speed for the same type of work. This is an important reason for doing a proper method study on a job before attempting to set a time standard. It enables the studyman to gain a clear understanding of the nature of the work and often enables him to eliminate excessive effort or judgment and so bring his rating process nearer to a simple assessment of speed.

In the next section some of the factors affecting the rate of working of the operative will be discussed.

6. FACTORS AFFECTING RATE OF WORKING

Variations in actual times for a particular element may be due to factors outside or within the control of the worker. Those outside his control may be—

Variations in the quality or other characteristics of the material used, although they may be within the prescribed tolerance limits.
Changes in the operating efficiency of tools or equipment within their useful life.
Minor and unavoidable changes in methods or conditions of operation.
Variations in the mental attention necessary for the performance of certain of the elements.
Changes in climatic and other surrounding conditions such as light, temperature, etc.

These can generally be accounted for by taking a sufficient number of studies to ensure that a representative sample of times is obtained.

Factors within his control may be—

Acceptable variations in the quality of the product.
Variations due to his ability.
Variations due to his attitude of mind, especially his attitude to the organisation for which he works.¹

The factors within the worker's control can affect the times of similarly described elements of work by affecting—

The pattern of his movements.
His working pace.
Both, in varying proportions.

The studyman must therefore have a clear idea of the pattern of movement which a qualified worker should follow, and how this pattern may be varied to meet the range of conditions which that worker may encounter. Highly repetitive work likely to run for long periods should have been studied in detail using refined method study techniques, and the worker should have been suitably trained in the patterns of movement appropriate to each element.

The optimum pace at which the worker will work depends on—

The physical effort demanded by the work.
The care required on the part of the worker.
His training and experience.

Greater physical effort will tend to slow up the pace. The ease with which the effort is made will also influence the pace. For example, an effort made in conditions where the operator cannot exert his strength in the most convenient way will be made much more slowly than one of the same magnitude in which he can exert his strength in a straightforward manner (for instance, pushing a car with one hand through the window on the steering wheel as opposed to pushing it from behind). Care must be taken to distinguish between slowing up due to effort and slowing up because of fatigue.

When the element is one in which the worker is heavily loaded, so that he has to exert considerable physical effort throughout, it is unlikely that he will perform it at anything other than his natural best pace. In such circumstances rating may be superfluous: it may be sufficient to determine the average of the actual times taken during an adequate number of observations. This was very strikingly shown during an I.L.O. study of manual earth-moving operations carried out in India. The workers—men, women and youths—carried loads of earth up to 38 kg in weight on their heads, in wicker baskets. A man with 38 kg on his head does not dawdle. He is anxious to get to the end of his walk and get rid of the load, and so performs the task at the best rate that he can naturally achieve. In doing so he shortens his stride, taking very short paces very quickly so that it looks almost as though he is going to break out into a trot at any moment. In point of fact, the stopwatch showed that the time taken over the loaded travel was a good deal longer than that needed for the apparently more leisurely return unloaded, so that the studyman without experience of the effort involved in the operation could very easily be led into making false ratings. In fact, for the loaded walk ratings...
Time Study: Rating

were not necessary, except when contingencies occurred. Similar heavily loaded elements occur in factories, as in carrying sacks, picking them up, or throwing them down onto stacks. These operations are most likely to be carried out at the best natural pace which the worker can manage.

An increased need for care in carrying out an element will reduce the pace. An example is placing a peg with parallel sides in a hole, which requires more care than if the peg is tapered.

Fumbling and hesitation on the part of the worker are factors which the studyman must learn to recognise and cope with. A worker's natural skill and dexterity combined with training and experience will reduce the introduction of minor method variations (fumbling), and also the foreign element "consider" (hesitation). Very slight deviations from the standard method can be taken into account by assigning a lower rating, but fumbling and hesitation usually signal a need for further training.

The studyman should be careful not to rate too highly when—

- The worker is worried or looks hurried.
- The worker is obviously being over-careful.
- The job looks difficult to the studyman.
- The studyman himself is working very fast, as when recording a short-element study.

Conversely, there is a danger of rating too low when—

- The worker makes the job look easy.
- The worker is using smooth, rhythmic movements.
- The worker does not pause to think when the studyman expects him to do so.
- The worker is performing heavy manual work.
- The studyman himself is tired.

The studyman must take such factors into account. Rating is very much easier if a good method study has been made first in which the activities calling for special skill or effort have been reduced to a minimum. The more the method has been simplified the less the element of skill to be assessed, and the more rating becomes a matter of simply judging pace.

7. SCALES OF RATING

In order that a comparison between the observed rate of working and the standard rate may be made effectively, it is necessary to have a numerical scale
against which to make the assessment. The rating can then be used as a factor by which the observed time can be multiplied to give the basic time, which is the time it would take the qualified worker, motivated to apply himself, to carry out the element at standard rating.

There are several scales of rating in use, the most common of which are those designated the 100-133 scale, the 60-80, the 75-100, and the British Standard scale used in this book (essentially a restatement of the 75-100 scale) which is the 0-100 scale.

Table 11 shows examples of various rates of working on the scales mentioned.

| TABLE 11. EXAMPLES OF VARIOUS RATES OF WORKING ON THE PRINCIPAL RATING SCALES |
|---|---|---|---|---|---|
| Scales | Description | Comparable walking speed* |
| 60-80 | 75-100 | 100-133 | 0-100 Standard | | |
| 0 | 0 | 0 | 0 | No activity. | |
| 40 | 50 | 67 | 50 | Very slow; clumsy, fumbling movements; operator appears half asleep, with no interest in the job. | 2 | 3.2 |
| 60 | 75 | 100 | 75 | Steady, deliberate, unhurried performance, as of a worker not on piecework but under proper supervision; looks slow, but time is not being intentionally wasted while under observation. | 3 | 4.8 |
| 80 | 100 | 133 | 100 (Standard Rating) | Brisk, businesslike performance, as of an average qualified worker on piecework; necessary standard of quality and accuracy achieved with confidence. | 4 | 6.4 |
| 100 | 125 | 167 | 125 | Very fast; operator exhibits a high degree of assurance, dexterity and co-ordination of movement, well above that of an average trained worker. | 5 | 8.0 |
| 120 | 150 | 200 | 150 | Exceptionally fast; requires intense effort and concentration, and is unlikely to be kept up for long periods; a “virtuoso” performance only achieved by a few outstanding workers. | 6 | 9.6 |

* Assuming an operator of average height and physique, unladen, walking in a straight line on a smooth level surface without obstructions.
In 100-133, 60-80 and 75-100 scales, the lower figure in each instance was defined as the rate of working of an operative on time rates of pay; and the higher, in each case one-third higher, corresponded to the rate of working we have called the standard rate, that of a qualified worker who is suitably motivated to apply himself to his work, as for instance by an incentive scheme. The underlying assumption was that workers on incentive perform, on average, about one-third more effectively than those who are not. This assumption has been well substantiated by practical experience over many years, but it is largely irrelevant in the construction of a rating scale. All the scales are linear. There is therefore no need to denote an intermediate point between zero and the figure chosen to represent the standard rating as we have defined it. Whichever scale is used, the final time standards derived should be equivalent, for the work itself does not change even though different scales are used to assess the rate at which it is being carried out.

The newer, 0-100 scale has, however, certain important advantages which have led to its adoption as the British Standard. It is commended to readers of this book and is used in all the examples which follow. In the 0-100 scale, 0 represents zero activity and 100 the normal rate of working of the motivated qualified worker; that is, the standard rate.

8. HOW THE RATING FACTOR IS USED

The figure 100 represents standard performance. If the studyman decides that the operation he is observing is being performed with less effective speed than his concept of standard he will use a factor of less than 100, say 90 or 75 or whatever he considers represents a proper assessment. If, on the other hand, he decides that the effective rate of working is above standard, he gives it a factor greater than 100: say 110, 115 or 120.

It is the usual practice to round off ratings to the nearest multiple of five on the scale; that is to say, if the rate is judged to be 13 per cent. above standard it would be put down at 115. During the first weeks of their training studymen are unlikely to be able to rate more closely than the nearest ten.

If the studyman's ratings were always impeccable, then however many times he rates and times an element the result should be that—

\[ \text{Observed Time} \times \text{Rating} = \text{A Constant} \]

provided that the element is of the type described as a constant element in section 6 of the last chapter, and that it is always performed in the same way.
The reader may be puzzled that in the figures above 0.20 × 100 is shown as equal to 0.20 rather than 20. It must be remembered, however, that rating does not stand by itself: it is always a comparison with the standard rating (100) so that when the amended time is being computed the assessed rating is the numerator of a fraction of which the denominator is the standard rating. In the case of the 100 standard this makes it a percentage which, when multiplied by the observed time, produces the constant known as the "basic time" for the element.

\[
\text{Observed Time} \times \frac{\text{Rating}}{\text{Standard Rating}} = \text{Basic Time}
\]

For example—

\[
0.16 \text{ min} \times \frac{125}{100} = 0.20 \text{ min}
\]

This basic time (0.20 min in the example) represents the time the element would take to perform (in the judgment of the observer) if the operator were working at the standard rate, instead of the faster one actually observed.

If the operator was judged to be working slower than the standard, then a basic time less than the observed time would be arrived at, for example—

\[
0.25 \text{ min} \times \frac{80}{100} = 0.20 \text{ min}
\]

In actual practice the multiple Observed Time × Rating is very rarely exactly constant when taken over a large number of readings for various reasons, e.g.:

- Variations in the work content of the element.
- Inaccuracies in noting and recording observed times.
- Inaccuracies in rating.
- Variations due to rating to the nearest five points.
9. RECORDING THE RATING

We have discussed the theory of rating at some length and are now in a position to undertake the complete study.

In general each element of activity must be rated during its performance before the time is recorded, without regard to previous or succeeding elements. No consideration should be given to the aspect of fatigue, since the allowance for recovery from fatigue will be assessed separately (see Chapter 17).

In the case of very short elements and cycles this may be difficult. If the work is repetitive it is possible to rate every cycle or possibly the complete study. This is done when the short cycle study form (figure 60) is used.

It is most important that the rating should be made while the element is in progress and that it should be noted before the time is taken, otherwise there is a very great risk that previous times and ratings for the same element will influence the assessment. For this reason the "Rating" column on the time study sheet in figures 58 and 59 is placed to the left of the "Watch Reading" column. It is, perhaps, a further advantage of the cumulative method of timing that the element time does not appear as a separate figure until the subtractions have been made later in the office. If it did, it might influence the rating or tempt the studyman to "rate by the watch".

Since the rating of an element represents the assessment of the average rate of performance for that element, the longer the element the more difficult it is for the studyman to adjust his judgment to that average. This is a strong argument in favour of making elements short, subject to the conditions discussed in Chapter 15. Long elements, though timed as a whole up to the break points, should be rated every half-minute.

Rating to the nearest five is found to give sufficient accuracy in the end result. Greater accuracy than this can be attained only with very long training and practice.

We may now refer back to the time study form in figures 58 and 59. We have discussed the filling in of two columns, namely "Watch Reading" (W.R.) and the "Rating" (R.), both entries being made on the same line.

These readings are continued for a sufficient number of cycles, at the end of which the watch is allowed to run on until compared with the clock with which it was synchronised when started. The "time after" can then be noted and recorded. The study is then at an end, and the next step, after thanking the operator for his co-operation, is to work out the basic time for each element. How to do this is described in the next chapter.
CHAPTER 17

FROM STUDY TO STANDARD TIME

1. SUMMARISING THE STUDY

At the stage we have now reached, the studyman has completed his observations at the workplace and has returned to the work study office with his study. No doubt he will later be making further studies on the same job or operation as performed by different operatives, but for the moment we shall consider how he works up the study he has just taken and enters the results obtained on the analysis of studies sheet for the operation. Later in the chapter we shall see how standard times are compiled from the entries on the analysis of studies sheet.

All the entries made so far on the time study top sheet (figure 58) and the continuation sheets (figure 59) have been written in pencil. Besides the heading details shown in the data block on the top sheet there will be the “time before”, the first entry on the study proper; the “time after”, which will be the last entry,
From Study to Standard Time

and two entries for each watch reading made—the rating and the watch reading itself. The ratings will all be in the column headed “R.” and will consist of numbers like 95, 115, 80, 100, 75, 105, etc., though until the studyman has had considerable practice he should confine his ratings to steps of ten, such as 80, 90, 100, etc. In the next column, that headed “W.R.”, will be the watch readings in decimal minutes. Since watch readings will have been made at intervals of half-a-minute or less (long elements being rated and timed every half-minute during the element as well as at the break point which signals its end) most of the entries will consist of two figures only, with a three-figure entry occurring whenever a full minute has been crossed. It is usual to omit the decimal points. This saves the studyman a certain amount of writing and in practice gives rise to no ambiguity.

Let us assume that the “time before” was 2.15 minutes. The first entry on the study proper will thus be 215. The next may be 27, indicating that the watch was read 2.27 minutes after it was started. If the next three entries are 39, 51 and 307, these will signify that the watch was read at 2.39, 2.51 and 3.07 minutes after it was started. Two- and three-figure entries will continue in this way down the sheet until 10 minutes have elapsed, when the next entry will be a four-figure one. Most studymen then revert to three-figure and two-figure entries again until another 10 minutes have passed, using four figures only for the first entries after the 10-minute intervals. The study will close with the “time after” entry, at which time also the “time off” will be noted in the data panel on the study top sheet. Every now and then in the study there may be watch readings without accompanying ratings, when some delay or stoppage has occurred. These of course cannot be rated, for they are not work.

It should be made a working rule that none of these pencil entries may ever be erased and replaced. Occasionally a study may contain a very obvious error which is of a sort which may be corrected without invalidating the study. If so, the correction should be made in ink, over the original pencil entry, so that it may always be seen later as a change made in the study office, not at the place where the study was made. Whenever there is an error about which there is doubt as to how it should be corrected that part of the study should be ignored. It may be necessary to scrap the study and make another.

It is good practice to carry out all subsequent work on the study sheets either in ink or in pencil of a different colour from that used for the initial recordings. Many study departments make this a standing rule also. There is then no doubt whatever about what was actually recorded from direct observation and what represents subsequent calculation. Quite apart from its merits in obtaining orderly processing of the data recorded, the practice helps also to maintain the confidence of workers and their representatives that nothing improper is permitted in the working up of studies.

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2. PREPARING THE STUDY SUMMARY SHEET

As will be seen a little later, much of the work necessary before the study summary sheet can be completed consists of quite simple routine calculation which may be done by a clerk while the studyman gets on with something else. In the beginning, however, the studyman should do everything himself, until he is so thoroughly familiar with all the procedures involved that he can not only instruct the clerk on what has to be done but can also check the calculations easily and quickly.

The first step is to complete the data at the head of the study summary sheet, copying the details neatly, in ink, from the study sheets. From the time off and the time on the elapsed time may be calculated and entered. When cumulative timing is being practised the elapsed time should of course agree with the final watch reading. If it does not there is an error which must at once be investigated. It is no use doing further work on the study until this is cleared up, for a serious error may be cause for scrapping the study and starting again. Deducting from the elapsed time the total “check time”—the sum of the “time before” and the “time after”—yields the net time. This should agree with the sum of all the observed times when using flyback timing, or the sum of all the subtracted times with cumulative timing. If flyback timing has been used this check should be made before proceeding further, by adding up all the element times recorded and seeing how the total compares with the net time. It is unlikely that there will be exact agreement, for the reasons noted earlier, but the discrepancy should be within 2 per cent. If it is greater than this, some departments make it their practice to ignore the study and make another.

When cumulative timing has been used the check cannot be made until the subtracted times have been obtained and totalled. The comparison then serves as a check on the accuracy with which the subtractions have been made. Any error should be investigated and corrected before the work of extension is undertaken.

On the body of the study summary sheet the studyman next lists in order all the repetitive elements observed, in order of their occurrence, noting the break points used on the reverse of the sheet.

Some of these repetitive elements may be variable elements, which will have to be treated in a different way from the constant elements. These variable elements are therefore listed again in a fresh tabulation below the full list of repetitive elements. Below the variable elements the studyman next lists any occasional elements observed, including with them any contingency elements of work which actually occurred during the study. Below these again are listed any foreign elements and ineffective time. When these entries have been made the sheet should provide for a summarised record of everything that has been observed during the study.
Enter Frequencies

The next step is to enter against each element listed on the study summary sheet the frequency with which that element occurred. Repetitive elements, by definition, occur at least once in every cycle of the operation so the entry to be made against a repetitive element will read 1/1, or 2/1, etc., indicating that the element concerned occurs once in every cycle (1/1), twice (2/1), or whatever may be the case. Occasional elements (for example, the element "sharpen tools") may occur only once every 10 or 50 cycles, when the entry would be 1/10, 1/50; or as appropriate. The entries are made in the column headed "F" on the study summary sheet.

3. EXTENSION: THE CALCULATION OF BASIC TIME

Having completed the entries in the heading block of the study summary sheet, listed the elements, entered frequencies, and (if necessary) made a clear sketch of the workplace layout on the reverse of the sheet, the studyman must turn next to the calculations which have to be made on the time study sheets themselves before he can go any further with his study summary. The results of his calculations will be entered on the time study sheets in ink or pencil of a different colour from that used when recording observations at the workplace.

If flyback timing has been used the studyman may proceed direct to extension. When using cumulative timing, however, it is first necessary to subtract each watch reading from the one following it in order to obtain the observed time for each element. The entries obtained in this way should properly be styled "subtracted times" rather than "observed times"; they are entered in the third column on the time study sheets, that headed "S.T.". The subtracted times derived when using cumulative timing are of course exactly equivalent to the observed times entered directly at the workplace when using flyback timing, so for simplicity the single term "observed time" is used during the rest of this chapter to connote both directly observed and subtracted times.

The next step is to convert each observed time to a basic time, entering the result in the column headed "B.T." on the time study sheets.

<table>
<thead>
<tr>
<th>Basic Time is the time for carrying out an element of work at standard rating, i.e.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed Time x Observed Rating</td>
</tr>
<tr>
<td>Standard Rating</td>
</tr>
<tr>
<td>Extension is the calculation of basic time from observed time.</td>
</tr>
</tbody>
</table>

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A slide rule is almost essential for extension, otherwise the process of multiplying a large number of times will become tedious and time-consuming. This operation can, however, be done by a clerk.

The effect of extending an observed time for an element to the basic time is shown graphically in figure 68.

**FIGURE 68. THE EFFECT OF EXTENSION ON THE TIME OF AN ELEMENT**

(a) Performance **above** standard

(b) Performance **below** standard

4. **THE SELECTED TIME**

The selected time is the time chosen as being representative of a group of times for an element or group of elements. These times may be either observed or basic and should be denoted as selected observed or selected basic times.

**Constant Elements**

In theory the results of all the computations of the basic time for any single constant element should be the same, but for the reasons given in the last chapter this is rarely so. It is necessary to select from all the basic times which have been
entered on the time study sheets a representative time for each element. This will be recorded against the element description on the study summary sheet and will later be transferred to the analysis of studies sheet as the end result of the study, at least in so far as that particular element is concerned.

The calculations necessary to arrive at the selected basic time are carried out on the working sheet. As was noted in Chapter 14, it is quite common to use simple lined sheets for making the analysis, or, for variable elements, squared paper, without having any special forms printed. The working sheets, when completed, are stapled to the time study sheets and filed with them.

Various methods are available for examining and selecting the representative basic time for a constant element. Perhaps the most common, and in many ways often the most satisfactory, is by making a straight average of the element times arrived at, adding all the computed basic times together and dividing the total by the number of occasions on which the element was recorded. Before doing this, however, it is usual to list all the basic times for the element and scrutinise the list, ringing out any times which are excessively high or low, well outside the normal range. These ringed times are sometimes styled rogues. They should be examined carefully.

An exceptionally high time may be due to an error in timing. If cumulative timing is being used an error of this sort will be revealed by examining the study, for an excessively long time for one element will cause shortening of the recorded time for the next. A high time may also be traceable to error in extension. But perhaps the most common cause, apart from errors, is that there has been some variation in the material being worked on or in some other aspect of the working method which has caused a higher work content on the particular occasion recorded. If so, it is necessary to establish the cause and to consider whether it is likely to recur frequently or only very rarely. If the latter, it is usual to exclude the element basic time from the total from which the average is derived and then, having computed the average time for the element, to carry the excess-over-average time contained in any ringed times down to contingencies, adding it to any other contingency time which may have been observed and recorded during the study. In this way the extra time is fully accounted for, but it is treated as an exceptional event or contingency, which it properly is. On the other hand, if minor variations in the work content of an element are at all common it will be much better not to exclude any computations at all when calculating the average. Frequent minor variations should always be treated as signals to alert the studyman. If they are unavoidable, they at least indicate that studywork will have to be continued until a large number of observations have been taken on the element concerned, so that the resulting average of all the basic times may be sufficiently representative. Very often, however, they indicate that a further study should be made of the operation to find out the reason for them, and, if possible, eliminate it. In a study made in India (mentioned earlier) very great variations were found in the times for

3 Page 27.
assembling and disassembling bolts and nuts, which led to an inquiry into the sources of supply.

Exceptionally short times should also be examined with great care. They too may be due to the studyman's error. On the other hand, they may indicate that a minor method improvement was adopted on the occasion which gave rise to the much shorter time than usual. If so it will be well to study the job again, giving special and more detailed attention to the working methods used.

The approach outlined above is valid so long as the exceptional times are either very infrequent, or, if frequent, only minor in character. Frequent large variations indicate that the element is not a constant one but a variable element, and it must be treated as such.

During a time study made on the operation of inspecting and jacketing this book, element B was described as: “Pick up 1 book, inspect, initial back end paper (break point: book closed)”. This element was observed 31 times, and the basic minutes computed were as shown below:

<table>
<thead>
<tr>
<th>Element B</th>
<th>Basic minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>26</td>
<td>28</td>
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<tr>
<td>27</td>
<td>27</td>
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<td>26</td>
<td>27</td>
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<tr>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>

It will be seen that one figure has been ringed, the basic time of 0.49 min which occurred when a faulty book was encountered, examined and rejected. Excluding this figure, the total of the remaining 30 basic times is 7.97 min, which yields an average of 0.266 min per occasion. At this stage in the studywork the figure 266 would be entered on the study summary sheet and be carried to the analysis of studies sheet, but at the end of the computations for the element the basic time finally selected would be rounded off to the nearest two figures—in this case 0.27 min. The excess work observed in the ringed observation (0.49 – 0.27 = 0.22) would be carried down to the contingencies record.

Selection by averaging in this way is simple to teach and to understand, and is readily accepted by both studymen and workers. When the total number of observations made on an element is relatively small, averaging usually gives a more accurate result than is obtainable with other methods of selection. It does,
however, give rise to a great deal of clerical work when many observations have been recorded, particularly when short elements have been observed very many times, and so other methods of selection have been devised to reduce the calculation effort required.

One method, which obviates the necessity for extending observed times to basic times, is to tabulate the observed times for the element under the ratings recorded as corresponding to each observation, so as to form a distribution table against ratings. The table can be compiled direct from the entries made on the time study sheets at the workplace. For the element “B” in the example above, the distribution table would appear as follows:

<table>
<thead>
<tr>
<th>Rating</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
<th>100</th>
<th>105</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed times</td>
<td>31</td>
<td>32</td>
<td>30</td>
<td>28</td>
<td>28</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>30</td>
<td>30</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>26</td>
<td>28</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
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<td></td>
<td>29</td>
<td>29</td>
<td>27</td>
<td>29</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Totals of observed times</td>
<td>31</td>
<td>155</td>
<td>258</td>
<td>195</td>
<td>190</td>
<td>27</td>
</tr>
<tr>
<td>Basic times</td>
<td>25</td>
<td>132</td>
<td>232</td>
<td>185</td>
<td>190</td>
<td>28</td>
</tr>
<tr>
<td>Total = 792</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the tabulation above, all the 30 observed times from which the basic times shown in the earlier example were computed are listed, the one ringed observation having been excluded. The observed times are then totalled under each rating, and these totals are then extended by multiplying by the corresponding ratings, to yield the basic times (totals) shown in the line below. The grand total of all these basic times comes to 7.92 min, which, when divided by 30 (the number of observations) gives the selected basic time for the element—0.264 min. This may be compared with the result of 0.266 min achieved by averaging the individual basic times.

A third method also avoids the necessity of extending each observed time, the selection being made by constructing a plot as shown in figure 69. In this method there are two sections to the plot, and two entries are made for each observation, but the entries are crosses or dots. The left-hand axis contains the time scale, and shows the range of times observed for the element, in this case from 26 to 32. The scale at the top of the right-hand part of the plot shows the ratings observed, from 80 to 105. To make the plot, the studyman runs down his study and each time the element is recorded he makes a cross against the time observed, and a second cross, also against the observed time but under the rating observed, on the right-hand side of the plot.
When all these entries are made the left-hand side of the diagram will exhibit a frequency distribution of observed times. On the right-hand side, the best straight line is drawn through the points plotted. The selected basic time for the element can then be read off by entering the right-hand plot under 100 rating, going vertically down until the line through the points is reached, and then reading on the scale at the left the time which corresponds to the intersection.

It is essential that the plot on the left-hand side be completed in order that it may be checked whether the distribution follows the normal pattern. If it does not, the method should not be used. Distributions which are irregular—lopsided, skewed, or having two humps—should be treated as signals that the method will not be reliable, at any rate in the simple form here described. The different distribution patterns which can be produced each have significant meanings, indicating different variations in the work itself, in the operative's rate of working, or in the studyman's rating efficiency, but it will be better not to get involved in sophisticated analyses of this sort until considerable experience has been gained. The method is illustrated briefly here because it is typical of several which make use of graphical means to select representative basic times without extending each observation. Most of them are valid only when the distribution is normal or when the precise significance of any abnormality is thoroughly understood. It is recommended that the graphical methods be avoided unless expert guidance is available. The first

FIGURE 69. A GRAPHICAL METHOD OF SELECTING BASIC TIME
two methods described will suffice for all normal needs, and have the merit that they are more easily understood by workers or their representatives.

Before leaving the subject of constant elements, the reader may like to refer again to the comments made in the last chapter about certain manual elements when the worker is heavily loaded, so that in all probability he normally performs the element at his best natural pace. Such elements are comparatively rare, but when they occur it may be sufficient to compute the selected basic time by simply averaging observed times, without recourse to extension. It is essential, however, to have a large number of observations if this is to be done.

Variable Elements

Variable elements present more difficulty in their analysis. It is necessary to find out what it is that causes the basic time to vary, and quite often there may be several variables to take account of at once. For example, consider the operation of cross-cutting wooden planks with a handsaw. The basic time needed to make the cut will vary with the width of the plank, which establishes the length of cut which has to be made, and also with the thickness of the planks and the hardness of the type of wood being cut. If the saw needs sharpening the cut will take longer, but this would be considered to be the use of an incorrect method, so any observations made while the operator is using a blunt saw would be disregarded.

The first step in the treatment of variable elements is almost always to extend observed times to basic times. The basic times will then be plotted on squared paper against the known variables. Thus for variable elements the analysis of studies sheet takes the form of graph paper, and the same graph which is constructed at the time of summarising the study will probably be attached to the analysis of studies sheet, in place of the entries made on this sheet for constant elements.

Whenever possible the basis chosen for the plot should be some variable which yields a straight line when the basic times are entered. Sometimes this can be done by using logarithmic paper, when analysis of the operation suggests that the variability with time may not be arithmetically linear. Quite often, however, it is not possible to discover a straight line relationship between time and the main variable, or with any combination of variables which is tried. In these cases the end product will be a curved line, drawn as smoothly as possible between all the plots made from all the studies on the element. Basic times for the element will then be selected by reading off the curve at the appropriate point on each occasion on which a standard time has to be compiled.

The treatment which the studyman would accord to the times derived from studying the cross-cutting of planks would depend on whether the operation is an

\[1 \text{ Pages 265-266.}\]
incidental one, performed only rarely, or whether it is an element performed many
times each day, forming a substantial proportion of the total work done. In the
latter case he will probably need to build up a series of graphs, each for a different
hardness of wood, and each graph having a family of lines on it, one for each
thickness of plank. Basic times would be plotted on these graphs against length
of cut. The relationship should be linear, so that once it has been discovered the
lines can be expressed as formulae, with factors to take into account the variables,
thus dispensing with the graphs for the computation of basic times. If the element
is not of sufficient importance to warrant so much detail the studyman would
probably try plotting basic times against the product: width of plank × thickness
of plank, thus combining two of the main variables, and would also try to establish
a factor by which to multiply the relationship discovered to take account of different
hardnesses of wood.

It will be evident that, in general, many more observations will be necessary
of a variable element than of a constant element before reliable representative
basic times can be established. It is well to recognise this at the outset, so that the
studywork can be planned to span all the different conditions and variables which
are likely to be encountered in practice. It is well also to give close attention from
the beginning to discovering the best basis against which to plot the times, essaying
trial plots against different possibilities until some satisfactory indicator of the
cause of the variable times is revealed. Once the basis of the relationship has been
discovered further studywork can be directed to making good gaps in the informa-
tion so far compiled. If the essential analysis is left until a later stage many of the
studies taken may turn out to be needless duplication.

It is not possible to prescribe any one method of approach which will yield
satisfactory results in the analysis of all variable elements. Each must be treated
on its merits. It is here, perhaps, more than anywhere else in time study that close
attention to the detailed methods of working is amply repaid, for without this it
will rarely be possible to discover just what it is that causes basic times to vary.
Even when the causes are known there is often scope for considerable ingenuity
in devising a simple basis which will reflect the major variables and reveal a definite
and repeatable relationship.

5. COMPLETING THE STUDY SUMMARY SHEET

Having completed his computations, the studyman is now ready to enter up
on the study summary sheet the information which will make it a clear and concise
record of all the results obtained from his observations at the workplace. Against
each of the constant elements listed on the sheet he will enter the selected basic
time for the element and the number of occasions on which the element was
observed. The frequencies of occurrence have already been entered. Against the
variable elements he will note the relationship between basic time and the control-
ling variable, if he has discovered this, or will record a reference to the graph sheet
or other study analysis sheet on which the basic times derived have been analysed.
To complete the summary he needs to enter a record of any occasional elements observed which have not already been included, and also any foreign elements which may have appeared during the study. Contingency elements and any contingency time extracted during the computations must be shown, and it is usual to express the contingency basic minutes as a percentage of the total basic minutes of repetitive work observed during the whole of the study, so that there may be a basis for comparing the contingencies occurring during one study with those in another.

All the entries which have so far been made represent work, in one form or another. All except any foreign elements will figure later in the computation of a standard time for the operation, and since they are all work they will all attract relaxation allowance (discussed later). Besides the elements of work, however, there may well have been periods when no work was done during the study, either because the operative was resting or because he was engaged on one or other of the activities which have been described earlier in this book as ineffective time. The time so spent must now be totalled and entered on the summary, and it is useful to analyse it into a few main categories, such as “relaxation”, “ineffective time”, etc. The entries will all be in terms of observed times, of course, for periods when no work is done cannot be rated.

6. HOW MANY STUDIES?

Only rarely are standard times computed on the basis of the results obtained from a single study. If the operation is one of only minor importance and is performed only occasionally it may be possible to derive a time of sufficient accuracy from a single study, provided that the study has covered enough cycles of the operation to give assurance that the conditions observed were fully representative, and all the important elements in the operation are constant elements. In the more usual case, however, it will be necessary to make several studies—perhaps very many studies if the operation is an important one, containing variable elements, each study spanning several cycles of the operation. When the working conditions vary studies must be made in each of the different sets of conditions which will be met with in practice: at different times of day if atmospheric conditions change markedly during the shift, for instance, and on all the types of material which have to be processed if the material is not rigidly standard.

The studyman must be prepared to study all the work involved in starting up at the beginning of a shift and in shutting down at the end of it. Start-up and shutdown times are part of the work and may need a separate work value, or they may be taken into account (if appropriate) by making an allowance for them when calculating the standard times for individual jobs. In industries such as printing, presses are not normally left inked up overnight as the ink would dry before morning. Time may have to be allowed for cleaning machines and the workplace, and for changing clothes in industries where special clothing is required. Activities
of this sort are not usually taken into account in the computation of standard times for individual jobs but are more often dealt with by time allowances. Allowances are discussed later in this chapter: at this point it is sufficient to note that studies will have to be made on all the ancillary and incidental activities which are undertaken during the working day before the matter of allowances can be properly considered.

It is not possible to say precisely how many cycles of each element must be observed before a representative basic time can be selected, for so much depends upon the local circumstances. When different studies taken by different studymen at different times and perhaps on the work of different operatives, but all on the same element, give the same results for that element, in terms of basic minutes, then enough cycles of that element have been observed and attention can be directed to something else. For a simple constant element this stage may be reached after a total of perhaps 20 or 30 cycles only, provided that the studyman is sure that all variations have been observed. On the other hand, when many variations have to be taken into account it may not be unusual to run to 200–300 observations of the same constant element.

**FIGURE 70. CUMULATIVE AVERAGE BASIC TIMES FOR A CONSTANT ELEMENT**

A simple method of determining when enough cycles of a constant element have been observed—enough, that is, to permit a representative basic time for the element to be selected—is to plot the cumulative average basic time for the element each time a study is made on it and summarised. The plot is started with the basic time derived from the first study. When the second study comes in, the figure then
plotted is the average calculated by adding the basic time from the first study times number of observations during the first study to the product (basic time multiplied by observations) from the second study, and then dividing by the total number of observations made during both studies. Further plots are made in the same fashion as successive studies are worked up. When the line on the graph ceases to “wag” and settles down at a constant level enough studies have been made on this element. An example is shown in figure 70.

With variable elements it is convenient to start by making several short studies which together span the full range of variability, so that an early attempt may be made to establish the relationship between basic time and the indicative variable. Subsequent studywork may then be directed to obtaining the information needed to complete, modify or validate the apparent relationship suggested by the first studies.

7. THE ANALYSIS OF STUDIES SHEET

An example of an “analysis of studies sheet” is shown in figure 64 (Chapter 14). The results obtained in each study on an operation are entered on this sheet by copying from the study summary sheet, as soon as the study has been worked up. A form of the type illustrated provides for a list of all the elements which make up a job or operation, and also for full details in respect of constant elements, repetitive and occasional, together with a record of the contingency and ineffective times observed. Graphs are appended to the sheet to record the results obtained from studying variable elements.

When it is considered that enough observations have been made, the next step is to compute the final representative basic times for each element. This is done on the analysis of studies sheet. The process of selection is essentially similar to that described in Section 4 of this chapter, the usual method being to calculate the over-all weighted average of all the basic times recorded for each element, disregarding any entries which subsequent studywork has shown to be erroneous. The weighted average is obtained by multiplying the basic time recorded from a study by the number of observations of the element made in that study, adding up the products so derived for all the studies, and dividing the total by the sum of all the observations made in all the studies.

Once these final representative basic times have been computed for each constant element it is a simple matter to calculate the basic time per cycle, per job or per operation for these elements, by multiplying the time per occasion by the frequency per cycle with which each element recurs. Variable elements cannot be dealt with in this way, of course. For them, the basic time may have to be read off the appropriate graph, or, if a straight-line relationship has been established, be calculated from the formula which expresses the line in algebraic terms.
If it is considered appropriate to make provision in the job time for contingencies, the allowance necessary is also calculated on the analysis of studies sheet. The first step in doing this is to compute the percentage which the total observed contingencies represent of the total other work observed. Time spent on contingencies is just as much work as that devoted to repetitive and occasional elements, so contingency time will also be recorded in basic minutes. If the percentage is a very small one it will probably be convenient to adopt the figure as the percentage allowance to be made, but if it comes out at more than about 4 or 5 per cent. the better course is to inquire into the causes of the contingencies so as to eliminate or reduce them as far as possible. When action of this sort has been taken as a result of the studies, the percentage observed during the earlier studywork will no longer be valid and it will be necessary to make fresh observations.

At the stage now reached a basic time has been built up for the job or operation, including all repetitive and occasional elements and also any small amount of extra work which may be met with occasionally as a contingency. The compilation has been done element by element, so that if at any time in the future the job is changed slightly, by deleting or changing an element or by adding a fresh one, it will not be necessary to restudy the whole job. The entries on the analysis of studies sheet will still hold good for all the unchanged elements in the new job sequence, so it will be possible to make a fresh compilation after studying only the new elements.

The basic time, however, forms only a part of the standard time which has to be established for the job or operation. Certain allowances must be added before the standard time can be derived. These allowances must now be discussed, but before doing so it is necessary to state clearly what is meant by two terms which have been mentioned frequently in the preceding pages but which have not yet been precisely defined; namely, work content and standard time.

8. WORK CONTENT

In the chapters at the beginning of this book the term “work content” was used frequently to describe what the words themselves suggest: the amount of work which has to be done to complete a job or operation, as distinct from any ineffective time which may occur. In time study practice, however, the word “work” is accorded a meaning which is slightly different from that which it normally has in ordinary English usage. An observer familiar with the word only in its usual sense who watched an operative at his job would say that when the worker was actually doing something he was working, and that when he was resting or doing nothing then he was not working. In time study practice, however, we are concerned to measure work in numerical terms, and for this purpose the word “work” is extended to include not only the physical labours performed but also the proper amount of relaxation or rest necessary to recover from the fatigue caused by those labours. We shall see later that relaxation allowances are made for other purposes besides recovery from fatigue, but for the moment the important point is that when
From Study to Standard Time

in time study we speak of "work" and set out to measure it, we define work to include the appropriate relaxation allowance, so that the amount of work in a job is taken as not only the time needed at standard performance to do whatever the job requires but also the additional time which is considered necessary for relaxation.

The work content of a job or operation is defined as:

basic time + relaxation allowance + any allowance for additional work — e.g. that part of contingency allowance which represents work.

9. STANDARD TIME

Standard time is the total time in which a job should be completed at standard performance — i.e. work content, contingency allowance for delay, unoccupied time and interference allowance, where applicable.

Allowances for unoccupied time and for interference are described later. They may be important for the measurement of machine-controlled operations, which are the subject of the next chapter, but they do not always appear in every computation of standard time. Relaxation allowance, on the other hand, has to be taken into account in every computation, whether the job is a simple manual one or a very complex operation requiring the simultaneous control of several machines. A contingency allowance will probably figure quite frequently in the compilation of standard times; it is therefore convenient to consider the contingency allowance and relaxation allowance first, so that the sequence of calculation which started with the completion of observations at the workplace may be taken right through to the compilation of standard time, at any rate in so far as simple manual operations are concerned.

10. CONTINGENCY ALLOWANCES

A contingency allowance is a small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays, the precise measurement of which is uneconomical because of their infrequent or irregular occurrence.
Contingency allowances have already been mentioned when describing the calculations which have to be made to complete the study summary sheet and the analysis of studies sheet. The allowance provides for small unavoidable delays as well as for occasional and minor extra work, and so it would be proper to split the allowance into these components, the contingency allowance for work being allowed to attract fatigue allowance, just as any other item of work does, and the delay part of the allowance being given with only a personal needs increment. In practice this is a distinction which is often ignored. Contingency allowances are always very small, and it is usual to express them as a percentage of the total repetitive basic minutes in the job, adding them on to the rest of the work in the job and adding a relaxation percentage to the whole contingency allowance. Contingency allowances should not be greater than 5 per cent., and should only be given in cases where the studyman is absolutely satisfied that the contingencies cannot be eliminated and that they are justified. On no account should such allowances be used as "loosening" factors or to avoid carrying out proper time study practice. The duties for which the contingency allowance is given should be specified. It may, however, in fairness, be necessary to give contingency allowances as a matter of course in enterprises where the shop work is not well organised. This further stresses the need to make the conditions and organisation of the shop as good as possible before setting time standards and is an incentive to the management to do so.

11. RELAXATION ALLOWANCES

Relaxation allowance is an addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of the allowance will depend on the nature of the job.

The relaxation allowance often forms the only major addition to the basic time and merits discussion at some length.

In the course of the method study which should have been undertaken before the job was timed, the energy expended in the performance of the operation should have been reduced to a minimum by the development of improved methods in accordance with the principles of motion economy and by the mechanisation, wherever practicable, of all really heavy work. Even when this has been done as far as is practicable, energy will still be expended and some allowance must therefore be made for recovery from the resulting fatigue.
Fatigue may be defined as a physical and/or mental weariness, real or imagined, existing in a person and adversely affecting his ability to perform work. The effects of fatigue can be lessened by rest pauses during which the body recovers from its exertion or by slowing down the rate of working and thus reducing the consumption of energy.

Intensive studies of industrial fatigue have been made in many countries. Among the pioneers were the Gilbreths (the founders of motion study) in the United States and the Industrial Health Research Board in Great Britain during and immediately after the First World War. A great deal of fundamental work has been done by physiologists and psychologists on the nature of fatigue and on recovery from fatigue, but much of this work has involved study of limiting fatigue, that is, testing subjects to the point of exhaustion or under extreme conditions of physical stress. These conditions are rarely met with in industry (if they are, something is wrong with the management of the undertaking). People working at industrial operations, with the exception of workers on very hot or heavy work (steel furnaces, for example), are usually working well within their physical and mental capacities. It is only comparatively recently that serious studies have been made in this latter field, and very little work indeed has been done on the allowances to be given for recovery from fatigue. A valuable attempt to fill in this serious gap has been made by the Max Planck Institut für Arbeitsphysiologie in Dortmund (Federal Republic of Germany), which has sponsored an important textbook on the subject.¹

In many of the countries for which this book is intended the problem of allowances for very hot and possibly humid climatic conditions is one of great importance. The subject is discussed separately later in this chapter. The reason for treating it separately is this. Allowances for fatigue in temperate climates are added element by element to the basic times, so that a work value for each element is built up separately, the element standard times being combined together to yield the standard time for the whole job or operation. It is possible to deal with any extra allowance which may be required to compensate for severe climatic conditions in this way, for the element may be performed at one time in cool weather and at another when it is very hot. Allowances for climatic variations have to be applied to the working day rather than to the element or job, in such a way that the amount of work which the operative is expected to produce over the day or shift is reduced. The standard time for the job remains the same, whether the job is performed in summer or winter, for it is intended to be a measure of the work which the job contains.

In spite of the work which has been and is being done on the subject of fatigue, relaxation allowances are still largely a matter of guesswork. Many scales of allowances, all of them attempts to achieve some sort of consistency in providing

¹ G. Lehmann: Praktische Arbeitsphysiologie (Stuttgart, Georg Thieme Verlag, 1953). See also the note on recent research on relaxation allowances at the end of Section 13.
for recovery from fatigue, have been drawn up for various types of activity and
different working conditions; most established management consultants in all
countries have their own. Many of them appear to work satisfactorily in practice.  
It is always well, however, when using one of the standard scales, to check the
amount of relaxation time which they yield by carrying out whole-day studies at
the workplace, noting the amount of time which the operatives actually spend in
relaxation of one form or another, and comparing this with the calculated allow-
ance. Checks of this sort do at least show whether the scale is likely to be, in
general, too tight or too loose.

It is important that whatever scale of allowances is used should be consistent,
and that when it is drawn up it should be agreed upon by all those whom it will
affect—or with their representatives.

Relaxation allowances are given as percentages of the basic time. When it is
considered that no one element of a job is any more or any less fatiguing than any
of the other elements, then the simplest course is to add all the element basic
minutes first and apply the allowance as a single percentage to the total. In many
jobs, however, the effort expended on different elements varies widely (where a
heavy workpiece has to be lifted onto and off a machine at the beginning and end
of an operation, for example), so the better practice is to add to each element the
allowance which it is considered that element merits.

In modern time study the studyman goes to great lengths to arrive at fair
and accurate time standards. These should not be spoilt by the hasty or ill-considered
addition of a few per cent. here and there “just in case”. Above all, rest allowances
should never be used as “loosening” factors.

For a simple manual operation the addition of the appropriate relaxation
allowance to the basic minutes for the elements of the job, plus the contingency
allowance, yields the standard time for the job. This is the total time in which the
job should be completed at standard performance. It may be thought of as the
“sustained performance time”—the time which should be allowed for the job
if performance is to be sustained at incentive level over an indefinite period without
adversely affecting the worker's health, provided, of course, that the job is being
carried out in a temperate climate.

Rest Pauses

The example of a time study shown in Chapter 19 indicates that even for
comparatively light work the relaxation allowance may amount to about 12 per

1 Recent evidence indicates, however, that many of the fatigue allowance scales which have been established
empirically, while satisfactory on physiological grounds for work involving normal or moderately intensive
effort, provide allowances which are inadequate when they are applied to very heavy operations and work in hot
conditions, such as operations connected with furnaces.
From Study to Standard Time

cent. of the basic time. On heavier work the allowance may be 20 per cent. or more.\(^1\) Allowances of between 12 and 20 per cent. mean that the worker is allowed to rest for a total of between one and one-and-a-half hours per eight-hour day. Many managers, seeing it stated like this, would say that such a large amount of rest was absurd and unnecessary. They might even say that their own workers never took so much rest. They would almost certainly be wrong. In nearly all factories and other establishments where the workers are on piecework there are a few who are very energetic and keen to earn extra money who take little or no rest. They, of course, benefit by earning a higher bonus than their fellows; but they are above average in strength or stamina. The average worker for whom the time standards are set needs adequate rest if he is going to keep up his rate of working, day in and day out, over the year. He usually takes it in small periods throughout the day, a few minutes here, a few minutes there, which are not noticeable individually but when added up total somewhere near the allowance permitted for the job.

There is no hard and fast rule governing the manner in which rest should be taken. There is evidence that short and frequent pauses delay the onset of fatigue more than longer pauses with long periods of work in between, but much depends on the nature of the work.\(^2\)

Early experimenters in motion and time study made operatives pause for short periods every few minutes, and early films show this being done in the case of men carrying pig-iron and other heavy loads. The idea of turning work and rest into a sort of "drill" has long since been given up in western countries. Nevertheless, it is generally agreed that rest pauses sanctioned by the management are more relaxing to the worker than those taken furtively when the foreman is not looking. One of the merits of sound time standards giving the operative a target of output for the day is that, provided he meets his target satisfactorily, he cannot fairly be accused of idleness if he is seen taking a rest pause: if no target is set it is difficult for him to defend himself.

A common method of dealing with pauses is to allow a ten to 15 minutes' break at mid-morning and mid-afternoon, often coupled with facilities for tea, coffee, or cold drinks and snacks, and to permit the remainder of the relaxation allowance to be taken at the discretion of the operative.

There is evidence to show that properly organised rest pauses are beneficial for the following reasons:

Rest pauses increase the amount of work which can be done in a day without unduly tiring the worker.

Workers like them as they break up the monotony of the day.

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\(^1\) Much more on very heavy operations.

\(^2\) See also the note on recent research on relaxation allowances at the end of Section 13.
Rest pauses decrease the variation in the operative's performance throughout the day and tend to maintain the level nearer the optimum.

Rest pauses reduce the amount of time off taken by workers during working hours.

It may be easier for the management to arrange the supply of snacks and refreshments in the workshop if rest breaks are taken at scheduled times.

On the other hand, the advent in recent years of automatic machines able to dispense instantly-brewed tea and coffee of very drinkable quality, as well as soft drinks, has led many managements to install these at suitable locations about the shop floor and dispense with organised rest pauses, leaving it to the workers themselves to decide when they want to break off work for a rest or a drink. The change has usually been welcomed by the workers, and has been generally found by managements to yield better results.

There are thus different views on the matter. Perhaps the conflict between them is more apparent than real. Probably organised rest pauses will be found better in workshops where the workers are paid on a time basis, and when facilities for refreshments cannot be made available all the time. When workers have been used to working under incentive conditions for some years, and when refreshments can be provided easily at any time, a change to the newer practice may be welcomed, for by this time managements too will have become used to measuring performance by results and will not look askance at workers who happen to be away from their work stations from time to time. When the work is of a heavy type, involving great physical effort or operation in very arduous conditions, it is desirable that proper rest pauses be enforced by the management and that the workers be required to move away from the work location during these breaks. Such enforced breaks should be sufficient to ensure that all the workers obtain enough relaxation to avoid danger to health. The workers will no doubt find it necessary to rest from time to time between the organised breaks, as well as during them, and they should be permitted to do this. It has to be borne in mind that many of the empirically established systems of assessing relaxation allowance do not have a sound physiological basis. There are indications that many of the non-physiological systems yield inadequate allowances when applied to very heavy or very hot work.

There is much truth in the saying "a change is as good as a rest". Just as it is beneficial to allow an operative who has been standing to sit for short periods, so a seated person should be allowed periods when he can stand and walk about. It is of some advantage at times to allow a seated operative to do some indirect work, such as fetching material from stores, just to make a change. In this way one type of work may act as relaxation for another, but the effect is difficult to measure.
Relaxation is sometimes taken in short pauses while actually performing an operation, and is often indicated by a slowing down in the performance as the operator tires.1

**Calculation of Relaxation Allowances**

The relaxation allowance has two components: a personal needs allowance, and a fatigue allowance.

The **personal needs allowance** provides for the necessity to go away from the workplace to attend to personal needs such as washing, going to the lavatory and getting a drink. Women require longer personal needs allowances than men. The allowance is made as a constant percentage, common figures being 5 per cent. for men and 7 per cent. for women.

The **fatigue allowance** always contains a constant basic allowance, and may have in addition a variable component of a size depending on how fatiguing the element is assessed to be. The constant portion of the fatigue allowance (the minimum or basic fatigue allowance) is that considered to be adequate for a worker who carries out the job while seated, who is engaged on light work in good working conditions, and who is called upon to make only normal use of hands, legs and senses. A common figure is 4 per cent., for both men and women. The variable addition is given only when the working conditions for the element are severe and cannot be improved. It is based on factors which vary according to the working conditions, and is often different in amount for men and women. There are also differences in the allowances considered appropriate by different authorities. An example of a set of allowances which has been widely used is given in table 12.

For the purposes of calculation, the relaxation allowance may thus be seen to be made up of—

- a **constant** allowance, always given, as a basic minimum;
- a **variable** addition, sometimes made, depending on the circumstances of the job.

If the figures quoted above are adopted, the **constant basic minimum allowance** becomes 9 per cent. for men (5 per cent. for personal needs plus 4 per cent. basic fatigue allowance), and 11 per cent. for women.

**Variable Additions to the Minimum Fatigue Allowance**

The following list embraces most of the factors likely to have to be taken into account:

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1 See also Section 4 of the next chapter, which contains a discussion of the length of pause which can be considered as available for recuperation from fatigue.
**TABLE 12. EXAMPLE OF A SYSTEM OF REST ALLOWANCES GIVEN AS PERCENTAGES OF BASIC TIMES**

<table>
<thead>
<tr>
<th>1. CONSTANT ALLOWANCES:</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Needs Allowance</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Basic Fatigue Allowance</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. VARIABLE ADDITIONS TO BASIC FATIGUE ALLOWANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Standing Allowance</strong></td>
</tr>
<tr>
<td>Slightly awkward</td>
</tr>
<tr>
<td>Awkward (bending)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

| **B. Abnormal Position Allowance**            |
| Slightly awkward                              | 0   | 1     |
| Awkward (bending)                             | 2   | 3     |
| **Very awkward (lying, stretching up)**       |     |

| **C. Weightlifting or Use of Force**          |
| **(lifting, pulling or pushing)**             |
| Weight lifted or force exerted (in kg)        |
| 2.5                                            | 0   | 1     |
| 5                                              | 1   | 2     |
| 7.5                                            | 2   | 3     |
| 10                                             | 3   | 4     |
| 12.5                                           | 4   | 6     |
| 15                                             | 6   | 9     |
| 17.5                                           | 8   | 12    |
| 20                                             | 10  | 15    |
| 22.5                                           | 12  | 18    |
| 25                                             | 14  |      |
| 30                                             | 19  |      |
| 40                                             | 33  |      |
| 50                                             | 58  |      |

| **D. Light Conditions**                       |
| Slightly below recommended value              | 0   | 0     |
| Well below                                    | 2   | 2     |
| Quite inadequate                              | 5   | 5     |

| **E. Air Conditions**                         |
| **(excluding climatic factors)**              |
| Well ventilated, or fresh air                 | 0   | 0     |
| Badly ventilated, but no toxic or injurious fumes | 5   | 5     |
| Work close to furnaces, etc.                  | 5-15 per cent. |

| **F. Visual Strain**                          |
| Fairly fine work                              | 0   | 0     |
| Fine or exacting                              | 2   | 2     |
| Very fine or very exacting                    | 5   | 5     |

| **G. Aural Strain**                           |
| Continuous                                    | 0   | 0     |
| Intermittent, loud                            | 2   | 2     |
| Intermittent, very loud                       | 5   | 5     |

| **H. Mental Strain**                          |
| Fairly complex process                        | 1   | 1     |
| Complex or wide span of attention             | 4   | 4     |
| Very complex                                  | 8   | 8     |

| **I. Monotony: Mental**                       |
| Low                                           | 0   | 0     |
| Medium                                        | 1   | 1     |
| High                                          | 4   | 4     |

| **J. Monotony: Physical**                     |
| Rather tedious                                | 0   | 0     |
| Tediou                                        | 2   | 1     |
| Very tedious                                  | 5   | 2     |

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1. Based on information supplied in 1956 by Personnel Administration Ltd. (now P.A. Management Consultants Ltd.).
2. See table 2, p.61.
3. See also the note on recent research on relaxation allowances at the end of Section 13.

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A. Standing.
B. Abnormal position.
C. Weightlifting or use of force.
D. Light conditions.
E. Air conditions.
F. Visual strain.
G. Aural strain.
H. Mental strain.
I. Monotony: mental.
J. Monotony: physical.

Examples of allowances for these factors are given in table 12. Some notes may, however, be helpful. Where allowance figures are suggested they are taken from table 12.

**A. Standing.** An additional allowance is given when an operative has to perform a job standing. Recent legislation in several countries has recognised the fact that extra effort is involved when a job is performed standing and provides for seats to be made available for relaxation periods at or near the workplace.

When the operation is performed standing, with the weight of the body carried normally on both feet, the suggested allowance is 2 per cent. for men and 4 per cent. for women. If the job requires standing on one foot only for an appreciable period, this is considered an abnormal position (q.v.).

**B. Abnormal position.** The natural position in western countries is standing or sitting with the work approximately waist high. Other positions may therefore be considered abnormal and an allowance given according to the amount of strain involved. The natural working position is not the same, however, in all countries; in India, for example, the squatting position may be considered normal.

Examples:
- Body weight not evenly distributed on both feet . . . 2 per cent. max.
- Body held inclined away from the vertical . . . . . . 5 " " "
- Arms held above chest (very tiring) . . . . . . . . . 10 " " "
- Body bent, stooping or lying . . . . . . . . . . . . . 5 " " "
- Confined position (miner at coal seam) . . . . . . . 6–8 " "

**C. Weightlifting or use of force.** The allowances in table 12 are for lifting or carrying weights in the most comfortable manner. If stooping or bending is necessary an allowance for abnormal position is added. The figures in the table indicate that as the load increases it becomes economically, as well as humanly, desirable to give mechanical assistance.

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The General Conference of the International Labour Organisation adopted a Maximum Weight Convention at its 51st Session in June 1967. The Convention is supplemented by a Recommendation which states as follows: "Where the maximum permissible weight which may be transported manually by one adult male worker is more than 55 kg (120 lb), measures should be taken as speedily as possible to reduce it to that level." Maximum weights to be carried by young and women workers should be "substantially less" than those assigned to adult male workers.

The figures quoted in table 12 have been taken from the curve shown in figure 71. It will be noted that, for weights above 30 kg, the additional fatigue allowance increases rapidly, reaching about 58 per cent. at a weight of 50 kg.

**FIGURE 71. ADDITIONAL FATIGUE ALLOWANCE NECESSARY WHEN LIFTING WEIGHTS OR EXERTING FORCE**
D. **Light conditions.** If the lighting provided is below that recommended in Chapter 6 (table 2, page 61) and it is impossible to improve it, an allowance should be given according to the amount of strain imposed. Bad light conditions may be due to glare, or to too great a contrast between the background and the working plane, as well as to lack of light.

E. **Air conditions.** The allowances suggested in table 12 are not intended to compensate for climatic variations (see Section 13 of this chapter) but to take account of unfavourable air conditions within the workshop which are due to features of the working process and which cannot be wholly eliminated. When an operative has to work in close proximity to unpleasant fumes an allowance of up to 15 per cent. may be called for, according to the severity of the conditions. If noxious fumes are present, so that a respirator has to be worn, an allowance of about 10 per cent. is often given. The figures in the table should be treated as being very approximate only. It will always be preferable to make efforts to improve the conditions, rather than simply giving an allowance.

F. **Visual strain.** Eyestrain may be caused by having to give very close attention to the workpiece or to the instrument being used, as in watchmaking or in watching a ring frame for yarn breaks.

Examples:

- Reading a micrometer or slide rule . . . . . . . . . . . . . 2 per cent.
- Ring frame tenting, light yarn . . . . . . . . . . . . . . . 2 " " "
- " " " dark " . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4 " " "

G. **Aural strain.** Perceptible strain occurs when a loud noise is made at irregular intervals, as in riveting; or when operatives are required to listen for changes in pitch, tone or noise level, as in testing certain types of machinery.

Examples:

- Normal testing of automobile engines . . . . . . . . . . . . 2 per cent.
- Overspeed testing of automobile engines . . . . . . . . . . 4 " " "
- Press shop or plate assembly shop noise . . . . . . . . . . . 2-3 " " "
- Pneumatic hammer, 5 seconds on, 5 off . . . . . . . . . . . 4 " " "

H. **Mental strain.** Mental strain may be caused by prolonged concentration—for instance trying to remember a long and complicated process sequence. (This is another good reason for recording all the details of every process, whenever possible.) It may also be caused by having to attend to a number of machines simultaneously (as in ring frame tenting or weaving), in which case it appears to be the result of anxiety.
Examples:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Spindles</th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring frame tenter, 200–300</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>700–800</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Weaver on non-automatic looms, 6 looms</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Weaver tending 24 automatic looms with auto-stop motions</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Ignition coil winding, 10 coils per mandrel</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

I. Mental monotony. Generally the result of the repeated use of certain mental faculties, as in mental arithmetic. It is more likely to occur in routine office activities than in the workshop. A change of work should be available.

J. Physical monotony (tediousness). The strain caused by the repeated use of certain members of the body, such as fingers, hands, arms and legs. Method study tends to make work more tedious for skilled operatives, but often enables the simplified work to be done by less skilled workers. Tedium may be alleviated by placing workers, especially girls, in positions where they can talk to their neighbours while working.

Examples:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cycle Time</th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very short cycle work, cycle time about 5 sec.</td>
<td></td>
<td>3–5</td>
</tr>
<tr>
<td>Short cycle work, cycles of 5–10 sec.</td>
<td></td>
<td>1–2</td>
</tr>
</tbody>
</table>

The relaxation allowance, given as a percentage of basic time, will normally be added element by element to each element of work listed on the analysis of studies sheet. The process of calculation of the allowances needed will be simplified if a special form like that shown in figure 86 (Chapter 19) is used. The allowances relating to the example being worked out are filled in on it.

12. THE STANDARD TIME

It is now possible to obtain a complete picture of the standard time for a straightforward manual job or operation, one which is considered to attract only the two allowances which have so far been discussed in detail: contingency allowance and relaxation allowance.

The standard time for the job will be the sum of the standard times for all the elements of which it is made up, due regard being paid to the frequencies with which the elements recur, plus the contingency allowance (with its relaxation allowance increment). The standard time may be represented graphically as follows:
In the case where the observed time is rated at less than standard pace, the rating factor will, of course, be shown inside the observed time. The contingencies and relaxation allowances are still, however, percentages of the basic time, even though it is less than the observed time (see figure 68 (b)). The standard time is expressed in standard minutes or standard hours.

13. RELAXATION ALLOWANCE IN HOT AND HUMID CLIMATES

A standard time calculated in the way which has been described is equally valid in whatever climate it is applied, so long as the details of the job and the methods of working are the same. What is not valid, however, is to expect the same number of standard minutes or standard hours of work to be produced in the course of a day. Hot and humid climates (and, of course, conditions of extreme cold) require that additional relaxation allowance be given. If it is applied as a factor varying the quantity of work expected over the day or shift, rather than as a modification of the standard times for jobs, it is easy to vary the allowances with the seasons or the atmospheric conditions from time to time.

The subject of relaxation allowances for hot climates is one about which very little is known, unfortunately. A programme of research was undertaken some years ago at the Ahmedabad Textile Research Association laboratories in India. Extensive research on steel workers in Sweden has been done by Professor Hohwü Christensen. An important series of experiments was carried out for three years by the Medical Research Council in the United Kingdom on the effect of climatic conditions on the performance of skilled tasks by young European men living in the tropics.1

When a human being does physical work, changes take place in his body according to the nature of the task and the amount of energy used in performing it. In general, the excess heat generated is dissipated by the process of perspiration. The rate at which this heat is lost depends on a number of factors, including—

- Surrounding air temperature (measured by dry-bulb thermometer).
- Humidity of surroundings (measured by wet-bulb thermometer).
- Rate of air movement.
- Presence of hot bodies, machines, walls, etc.

The effect of the first three factors can be measured by means of the wet kata thermometer. This instrument gives an indication of the rate at which heat can be absorbed by the surrounding atmosphere in millicalories per square centimetre per second. The higher the reading the more comfortable the working conditions.

If the kata reading should drop as low as 2 a worker will probably be unable to perform any work at all, since the body is unable to increase its rate of loss of heat above the rate necessary when it is at rest.

There is a general belief that natives of countries with very hot climates support high temperatures better than those from countries with temperate climates. Experience of members of I.L.O. productivity missions in India and Pakistan suggests that this is not so. Provided Europeans are properly dressed, once they are acclimatised, heat, as such, does not seriously affect their rate of working as compared with that of Indians or Pakistanis. They do, however, appear to suffer more from a combination of heat and high humidity owing to a tendency to perspire more and to develop "prickly heat".

This is borne out by Pepler's research on young Europeans in tropical climates, carried out at Singapore over a period of three years. These men were acclimatised, having been at least six months in the tropics.

One of the findings was that they carried out the tasks allotted them with the minimum number of errors at dry- and wet-bulb temperatures of 80-90 degrees Fahrenheit, and their performances deteriorated at temperatures both hotter and colder. This was the temperature to which they had become accustomed from day to day although it was far higher than the normal temperatures in the United Kingdom, for instance.

Table 13 was compiled from figures provided by the late Professor T. U. Matthew of the University of Birmingham, England, who was the leader of the first I.L.O. productivity mission to India. The figures are intended for use with the wet kata

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1 Some notes on the use of the wet kata thermometer are given in Appendix 6.
2 R. D. Pepler, op. cit.
thermometer. They must be regarded as strictly tentative but may provide a rough guide until more authoritative information is forthcoming. Although they were compiled some 15 years ago little further work appears to have been done on the subject.1

TABLE 13. TENTATIVE RELAXATION ALLOWANCES FOR ATMOSPHERIC CONDITIONS AT SELECTED KATA READINGS AT HIGH TEMPERATURES

<table>
<thead>
<tr>
<th>Cooling power (in millicalories per sq. cm./sec.)</th>
<th>Percentage rest per shift for acclimatised persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

It will be noted that the above rest allowances are given as a percentage of the shift; that is, when the cooling power is 2, 100 per cent. of the shift is necessary as rest. In other words, no work can be undertaken.

Further work on this subject is urgently required to enable the appropriate rest allowances for high temperatures and humidities to be determined.

It is important to note that proper rest from work under abnormal atmospheric conditions can only be taken away from those conditions.

The following examples are taken from conditions in a number of textile mills in India in which members of the first I.L.O. productivity mission worked. The allowances were calculated for acclimatised persons.

It will often be found that even a small increase in the rate of air movement will bring about a disproportionate improvement in the working conditions.

Research at the College of Aeronautics at Cranfield (England) suggested that the most suitable basis for the allocation of rest allowances for hot conditions may be the predicted sweat flow over four hours. Nomograms have been constructed.

1See note on recent research on relaxation allowances at the end of Section 13.
From Study to Standard Time

from which the sweat flow in litres at various dry- and wet-bulb temperatures and rates of air flow can be derived, and a tentative table of rest allowances has been produced. The figures have not yet been confirmed; this was, however, the first systematic attempt known to the I.L.O. to relate heat stress to time study allowances, and it may prove to be of great value.¹

### TABLE 14. EXAMPLES OF INCREASES IN RELAXATION ALLOWANCES AS A RESULT OF FALLS IN COOLING POWER

<table>
<thead>
<tr>
<th>Temperature (Celsius)</th>
<th>Cooling power (kata)</th>
<th>Tentative additional relaxation allowance (percentage of shift)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry-bulb</td>
<td>Wet-bulb</td>
<td></td>
</tr>
<tr>
<td>36.7</td>
<td>30.6</td>
<td>5.30</td>
</tr>
<tr>
<td>36.1</td>
<td>30.6</td>
<td>4.65</td>
</tr>
<tr>
<td>35.6</td>
<td>30.6</td>
<td>3.42</td>
</tr>
</tbody>
</table>

It is obvious that if allowances of this size have to be given to offset atmospheric conditions it is in the economic interest of the employer to install efficient air-conditioning plant. Even if such allowances are not officially given, the equivalent rest will be taken, since there is a limit to human endurance. This has been observed to be the case in all hot countries.

The rest allowance for hot and humid atmospheric conditions has been dealt with at some length in view of the circulation of this book in countries where such conditions prevail. Work study men who have to set standards in such conditions should take every opportunity to gather as much information on the subject as possible. In particular they should seek the advice of the government departments responsible for supervising working conditions.

**Inadequately Nourished Workforces**

Problems analogous to those discussed above arise when one has to consider the work output which may be expected from workers who are inadequately nourished and who may be suffering from chronic malnutrition. This is a situation which, unfortunately, is not uncommon in poorer countries; it is one in which, as has been observed earlier, employers will probably find it economically (as well as humanly) desirable to provide well-balanced meals for their workers, and perhaps subsidised food shops. Malnutrition takes a long time to remedy, however, though substantial improvements in health and stamina can be looked for

¹ J.A.C. WILLIAMS: Method Study of Hot Working Conditions. CoA Note No. 46 (Cranfield, United Kingdom, College of Aeronautics).
From Study to Standard Time

after a few months of proper diets. If time standards are to be used as the basis for incentive payments or workload allocations for workers who are inadequately fed it is essential that some allowance should be made to take account of their reduced capacity.

Time standards should properly be set having regard to the rate of working of a "qualified" worker. The definition of a qualified worker given on page 238 starts: "A qualified worker is one who is accepted as having the necessary physical attributes..." It is obvious that no worker who is chronically undernourished can be regarded as having the necessary physical attributes for any sustained and arduous manual task. It may well be that there are only a few really fit workers in the group observed, or none at all, so that the "representative" worker may not be a "qualified" worker. (See page 238 for a discussion of representative and qualified workers.)

This would seem at first sight to present a formidable obstacle to the setting of time standards in the manner which has been described in this book as representing good international procedure. In practice, however, it is usually found that even inadequately nourished workers normally perform elements of their work at a pace which is comparable with the standard pace, when suitably motivated, though of course they are not able to sustain normal rates of working for such long periods as well-fed workers are. Any extra relaxation allowance considered necessary is therefore best given as a percentage of the working shift, rather than as a modification of standard times, following the approach suggested above for relaxation allowances in hot and humid climates. Thus instead of looking for an output of 480 standard minutes of work in an eight-hour shift, some lower figure should be designated as the standard performance in the local circumstances.

A number of studies on nutritional intakes have been carried out in various countries but (so far as is known to the I.L.O.) there is very little documentation indeed on the relationship between measured work outputs and undernourishment in circumstances in which work study has been applied. Studies were made in India over a period of some 12 months on poorly fed workers digging and carrying earth on large construction projects, and these showed significant differences in daily outputs between better-fed and less well-fed workers. In the absence of sufficient data to draw up generalised rules for allowances in all sorts of conditions the work study man can do no better than to adopt the practice followed during these studies: that is, to carry out a series of whole-day studies on different groups of workers to discover the actual amounts of rest which they customarily take during the day. If a sufficient number of studies are taken in different climatic conditions, tentative allowances, as proportions of the working shift, can be built up.

If the studies are combined with wet kata thermometer readings it may prove practical to take account of climatic and nutritional factors in a single combined allowance.
Note on Recent Research on Relaxation Allowances

An important addition to the literature on the subject of relaxation allowances and rest pauses has been published in the Federal Republic of Germany.¹

The authors have carried out a systematic and comprehensive review of many current systems of assessing relaxation allowances, including both empirical systems (such as that described in Introduction to Work Study) and systems based on physiological measurements and making use of energy consumption estimates. It is pointed out that some systems are regarded as "trade secrets" by their exponents so that the values used in making fatigue allowance calculations are not disclosed to the workers, and sometimes not to management either. The authors strongly support the practice advocated by the I.L.O. in this regard, which is that the methods used for assessing relaxation allowances, the scales applied, and the procedures for regulating rest pauses should be openly discussed between management and workers' representatives, and should be freely agreed before being adopted.

Evidence is adduced to indicate that many of the empirical analytical systems, including that set out in Introduction to Work Study, while acceptable on physiological grounds for the general run of light and medium work in industry, yield allowances which are inadequate when applied to operations involving very heavy strains or work in hot conditions, such as are sometimes encountered when tending furnaces. For such conditions systems founded on physiological observations are preferred, and the authors propose a method which they have developed after some years of experiment. The method has been very carefully devised and takes into account a wide variety of strains. The results which accrue from applying it to the severer industrial operations will be of extreme interest. Most of the physiologically oriented systems require a good deal more clerical effort for their application than empirical systems, and sometimes specialised knowledge as well, but this will be amply justified if simpler methods do not yield adequate allowances for the most arduous tasks.

The authors draw attention particularly to the system described in Introduction to Work Study, and also to that advocated by the Bureau des Temps Elémentaires, Paris, which is similar in general concept and is considered to take sufficient account of the physiological knowledge of the subject to date.

The book, which is at present available in German only, is intended principally to be instrumental in improving the relaxation allowance practice in industry in the Federal Republic of Germany, which apparently differs in many respects from that advocated in Introduction to Work Study. According to the authors, workers in their country are not forbidden to pause occasionally, but

many contracts stipulate that they take breaks at their own cost. The authors therefore lay stress on the desirability of paid recuperation or relaxation allowances and on giving careful attention to the organisation of rest breaks and the provision of facilities for the workers to leave their workplaces during pauses. A pause during which the worker has to attend or supervise his machine or process cannot be considered as fully available for recuperation from fatigue. Similar conditions apply to the designation of waiting time during the shift (such as waiting for material supply), time while being instructed, preparation time and clean-up time as breaks which may be offset against calculated fatigue allowances. A non-working period at the beginning of a shift is obviously of no value whatever for the recuperation of fatigue incurred later on.

The authors have made a review of the various systems of organising rest pauses and have suggested suitable applications for each. Their conclusions represent the most comprehensive analysis of this subject known to the I.L.O.

In general, the authors endorse the practices advocated in the first edition of Introduction to Work Study (now expanded and revised in the present volume), subject to reservations about the physiological adequacy of fatigue allowances for tasks involving very heavy strains.

14. OTHER ALLOWANCES

It is sometimes necessary to incorporate allowances other than contingency and relaxation allowances in the compilation of standard times. Two such allowances—unoccupied time allowance and interference allowance—were mentioned briefly when defining standard time in Section 8 of this chapter. These allowances are made when setting times for operations concerned with the working of machines, and will be discussed in the next chapter. In the remaining part of this chapter certain allowances which are not normally incorporated in the standard time are described.

Special Allowances

Special allowances may be given for any activities not normally part of the operation cycle but essential to the satisfactory performance of the work. Such allowances may be permanent or temporary; care should be taken to specify which. Wherever possible these allowances should be determined by time study or production study (see Chapter 21).

When time standards are used as the basis for a payment-by-results scheme it may be necessary to make a start-up allowance to compensate for time taken by any work and any enforced waiting time which necessarily occurs at the start of a shift or work period before production can begin. A shut-down allowance may
similarly be given for work or waiting time occurring at the end of the day. A **cleaning allowance** is of much the same character: it is given when it is necessary for the worker to give attention from time to time to cleaning his machine or workplace. **Tool allowance** is an allowance of time to cover adjustment and maintenance of tools.

It would be possible, having studied the time necessary to perform any or all of these activities, to express the result as a percentage of the total basic time for the operations expected to be performed during a day and to give the allowance as an increment included in the compilation of standard times. Indeed, this is sometimes thought to be the better course with tool allowance, but in general it is preferable to give all these allowances as periods of time **per day** rather than embodying them in the standard times. Usually this is fairer to the operatives, and it has the signal advantage of bringing to the attention of management the total amount of time which has to be devoted to these activities, thus prompting thoughts about how it could be reduced.

Some allowances are normally given **per occasion** or **per batch**. One such is **set-up allowance**, given to cover the time required for preparing a machine or process for production, an operation which is usually necessary at the start of production on a batch of fresh products or components. Set-up time is sometimes called make-ready time: its opposite is tear-down or dismantling time, for which a **dismantling allowance** may be given, to cover the time needed for making alterations to machine or process settings after completing a run of production. Very similar is **change-over allowance**, usually given to operatives who are not actually engaged in setting-up or dismantling, to compensate them for time on necessary activities or waiting time at the start and/or the end of a job or batch. These allowances should be denoted as “job change-over allowance” or “batch change-over allowance”, as appropriate.

A **reject allowance** may be included in a standard time when the production of a proportion of defective products is **inherent** in the process, but is perhaps more usually given as a temporary addition to standard times, per job or per batch, if an occasional bad lot of material has to be worked. An **excess work allowance**, if necessary, would also be given as an addition to the standard time, to compensate for extra work occasioned by a temporary departure from standard conditions.

**Learning allowances** may be given to trainee operatives engaged on work for which standard times have been issued, as a temporary benefit while they develop their ability. A **training allowance** is a similar allowance given to an experienced worker to compensate him for the time he is required to spend instructing a trainee, while both are working on jobs for which standard times have been set. These allowances are often given as so many minutes per hour, on a declining scale so that the allowances taper off to zero over the expected learning period. Very similar is an **implementation allowance**, given to workers asked to adopt a
new method or process to encourage them to attempt an enthusiastic implementation of the new ways and prevent their losing earnings by doing so. In fact it is sometimes arranged that their earnings will actually be increased during the change-over period, so as to give the new method every chance of success. One system of implementation allowances credits the workers with ten minutes per hour on the first day, nine on the second, and so on down to zero.

Policy Allowances

A policy allowance is an increment, other than bonus increment, applied to standard time (or some constituent part of it, e.g. work content) to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstances.

Policy allowances are not a genuine part of time study and should be used with the utmost caution and only in clearly defined circumstances. They should always be dealt with quite separately from basic times, and, if used at all, should preferably be arranged as an addition to standard times, so as not to interfere with the time standards set by time study.

The usual reason for making a policy allowance is to line up standard times with the requirements of wage agreements between employers and trade unions. In the United Kingdom, for example, the incentive performance is generally set at such a level that the average qualified worker, as defined, can earn a bonus of $33\frac{1}{8}$ per cent. of his basic time rate if he achieves standard performance. There is no need to apply a policy allowance to achieve this state of affairs; it is simply necessary to arrange for the rate paid per standard minute of work produced to be $133\frac{1}{9}$ per cent. of the basic time rate per minute, and in general it is better to accommodate any special wage requirements in this way, by adjusting the rate paid per unit of work rather than the standard time.

There are, however, certain employer-union agreements under which higher bonuses can be earned, and it may not be politic to seek a revision of the terms of these agreements to permit the achievement of their terms by modifying the rates paid rather than the times set. In these circumstances a policy allowance is given to make up the difference. It may be applied as a factor to the work content or to the standard time.

This might be an appropriate course to take when standard times are being introduced to only a small proportion of the total workforce covered by the agreement. Similar policy allowances are sometimes made as temporary additions to
cover abnormal circumstances, such as the imperfect functioning of a piece of plant or disruption of normal working caused by rearrangements or alterations.

* *
* * *

In the next chapter the application of time study to operations involving the use of machinery, in which part of the operation time is taken up by work done by the machine while the operator stands by, is described. An example of a fully worked time study is shown in Chapter 19.
In the last four chapters the basic procedures of time study as applied to manual operations have been described. The techniques and methods which have been discussed allow time standards to be compiled for all jobs in which the operative works with hand tools or with power tools which he himself manoeuvres, as distinct from machines which perform part of the operation automatically. Such work is known as unrestricted work, because the output of the worker is limited only by factors within his control. A man grinding a cutting tool on an electrically operated grindstone is engaged on unrestricted work, and so is a worker polishing a metal component by holding it against a power-driven polishing mop, for in neither of these cases does the worker clamp the workpiece securely in position and leave the machine to get on with the work.

However, it is becoming increasingly common for industrial jobs to be made up partly of elements performed manually by the worker and partly of elements carried out automatically by machines or process equipment, the worker either
being necessarily idle meanwhile or attending to something else. In order to set
time standards for such operations it is necessary to apply somewhat different
methods, in extension of the basic time study procedures. For some highly complex
operations special techniques have been devised. Descriptions of them will be
found in specialised and advanced books on work measurement, references to
some of which are given in the footnotes and in the bibliography at the end of this
book. In the present chapter only the more generally applicable methods will be
described.

1. PLANT AND MACHINE CONTROL

Plant and machine control is the name given to the
procedures and means by which efficiency and utilisa-
tion of units of plant and machinery are planned and
checked.

In many enterprises the machines, plant and equipment together account for
by far the greatest proportion of the total capital invested in the undertaking.
When this is so the costs incurred in servicing capital, in maintaining the machines,
and in providing against depreciation and for the replacement of the equipment
may well amount in total to more than any other factory expense (excluding the
cost of raw materials and bought components, which is an external rather than a
factory expense). Very often these machinery costs are much greater than the
total wage bill for the plant, so that it is of the utmost importance to make the
most intensive use possible of the machinery and equipment installed, even though
this be done at the expense of labour productivity. Indeed, it may be very sound
policy to increase the manning complement on the machines, if by so doing
greater machine utilisation can be achieved.

Before turning attention to individual jobs, therefore, the work study man
will do well to examine first the over-all utilisation of the machinery in the business;
in the enterprise as a whole; in the different departments; and machine by machine
in the case of particularly expensive items. He will then be better placed to
decide the proper objectives for the application of work study in the plant, and
will see clearly whether labour productivity or machine utilisation is of primary
importance.

The terms and concepts used in the study of machine utilisation (or plant or
process utilisation) are described below. They are largely self-explanatory. The
relationship between them is shown graphically in figure 73.
**Machine maximum time** is the maximum possible time which a machine or group of machines could work within a given period, e.g. 168 hours in one week or 24 hours in one day.

**Machine available time** is the time which a machine could work based on attendance time—i.e. working day or week plus overtime.

**Machine idle time** is the time during which a machine is available for production or ancillary work but is not used owing to shortage of work, materials or workers, including the time that the plant is out of balance.

**Machine ancillary time** is the time when a machine is temporarily out of productive use owing to change-overs, setting, cleaning, etc.

**Machine down time** is the time during which a machine cannot be operated on production or ancillary work owing to breakdown, maintenance requirements, or for other similar reasons.

**Machine running time** is the time during which a machine is actually operating, i.e. the machine available time less any machine down time, machine idle time, or machine ancillary time.

The machine running time is a matter of fact, observable by direct study at the workplace. It does not follow, however, that the machine, though running, is actually operating in the manner in which it should, or has been set so as to perform in the very best manner of which it is capable. It is useful therefore to introduce another concept—

**Machine running time at standard.** This is the running time that should be incurred in producing the output if the machine is working under optimum conditions.

The most useful work measurement techniques for studies on machine utilisation are production study and activity sampling\(^1\), particularly the latter. These techniques enable the information required to be obtained with much less effort than would be needed with time study, especially when many machines are involved.

\(^1\) These techniques are described in Chapter 21.
It is convenient to express the results obtained from studies on machine utilisation in the form of ratios or indices. For this purpose three indices are commonly used—

**Machine utilisation index**, which is the ratio of machine running time to machine available time and thus shows the proportion of the total working hours during which the machine has been kept running.

**Machine efficiency index**, the ratio of machine running time at standard to machine running time

A ratio of 1.0 (or 100 per cent., as it would usually be expressed) would indicate the ideal state, with the machine always performing to the best of its capability whenever it is running.

**Machine effective utilisation index**, the ratio of machine running time at standard to machine available time

This ratio can be used to provide an indication of the scope for cost reduction that would be available if the machine were operated at full efficiency for the whole of the working time.

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1 Based on a diagram contained in the *British Standard Glossary of Terms in Work Study.*
When work measurement has been applied throughout an organisation it is an easy matter to arrange for these indices and others like them to be reported to top management as routine at regular intervals, for they can be calculated quite simply from the records instituted to maintain labour, output and machine controls. The incidence of idle time, down time and ancillary time can be highlighted by expressing these figures as ratios in a similar way, using either machine available time or machine running time as the base.

In process industries utilisation studies are carried out in much the same way, the terms and concepts being applied in the same fashion but substituting "process" or other suitable word for "machine". The principles are exactly the same when utilisation in service undertakings is considered: in a passenger transport undertaking, for example, the same useful results could be expected to accrue from studying the utilisation of buses or trains and expressing the results being achieved in the form of indices similar to those described above. This has been done with good effect in several surveys of public bus undertakings with which I.L.O. experts have been concerned.

2. RESTRICTED WORK

Restricted work is work in which the output of the worker is limited by factors outside the control of the worker.

A common example of restricted work is when an operator is running a single machine and the machine works automatically for part of the work cycle. The operator may perform the manual elements of his task at standard pace, faster, or slower, but while this will influence the rate at which the operation is completed it will not govern it, for the time during which the machine is working automatically will remain the same whatever the worker does.

This does not mean, of course, that nothing can be done to shorten the cycle time. The example of finish-milling a casting on a vertical milling machine which was discussed in Chapter 10 (pages 153–156, figures 36 and 37) shows what can be achieved by arranging for some of the manual elements which were formerly carried out while the machine was stopped to be done while the machine is running automatically, cutting the next casting. The reduction in cycle time which was achieved is shown graphically in figure 74, which compares the situation before and after the method study. (A time study on this operation is shown fully worked out in the next chapter.)
Time Standards for Machine Working

FIGURE 74. RESULT OF METHOD STUDY ON MILLING OPERATION

BEFORE method study

Operator working

Machine idle

1.20 min

Operator idle

Machine working

0.80 min

AFTER method study

Operator working

Machine idle

1.12 min

Operator idle

Machine working

0.80 min

Cycle time = 1.36 min

Cycle time = 2.00 min

In this example the machine element remains the same in both cases and takes 0.80 min, but the cycle time has been reduced from 2 min to 1.36 min, a reduction of 32 per cent. In the improved method the operator needs 1.12 min at standard pace to perform the manual elements of the job, but some of these are carried out while the machine is working. Even if the operator were to do all his manual work at twice the standard pace this would not reduce the cycle time by half, but only by some 20 per cent. Thus the output of the worker is limited by factors outside his control: the work is “restricted”.

Other examples of restricted work occur when—

(1) One or more operators are running several machines under conditions similar to those described above.

(2) Operators are in control of processes, their principal duties being to observe the behaviour of the processes or instruments recording their behaviour and to take action only in response to changes in behaviour, state or reading.

(3) Two or more operatives are working as a team dependent on one another and it proves impossible completely to balance the work-
load of each, with the result that some workers are left with periods of idleness within the work cycle.

Team working can give rise to restricted work even when no machines are used. Assembly work carried out in conjunction with moving conveyors usually does. Even if the conveyor is used simply to transport pieces from one work station to the next, each operative taking a component off the belt to work on it and returning it when he has done, a restriction may be imposed by having to wait for the next piece. And when assembly operations are carried out directly on the moving conveyor, as is done in motor vehicle manufacture, the conveyor produces conditions equivalent to those imposed by a static production machine.

It will be convenient to examine first the simpler case of one worker operating one machine, before considering multi-machine operation.

3. ONE MAN AND ONE MACHINE

The usual way of depicting graphically and on a time scale a one-man-and-one-machine operation is as in figure 75, which shows the improved method for the milling machine example quoted above.

The period during which the machine is working is known as the “machine-controlled time”.

**Machine-controlled time (alternatively process-controlled time) is the time taken to complete that part of the work cycle which is determined only by technical factors peculiar to the machine (or process).**

It will be seen that the operative carries out part of his manual work while the machine is stopped, and part while it is running. These parts are called “outside work” and “inside work”, respectively.

**Outside work comprises elements which must necessarily be performed by a worker outside the machine- (or process-) controlled time.**

**Inside work comprises those elements which can be performed by a worker within the machine- (or process-) controlled time.**
Finally, there is the time during which the operative is waiting for the machine to complete the cut, i.e. his "unoccupied time".

**Unoccupied time comprises the periods during machine-(or process-) controlled time when a worker is neither engaged on inside work nor in taking authorised rest.**

**FIGURE 75. MILLING OPERATION: IMPROVED METHOD**

- Cycle time: 1.36 min
- Machine-controlled time: 0.80 min
- Outside work: 0.56 min
- Inside work: 0.56 min
- Unoccupied time: 0.24 min

In diagrams of this sort the periods of time during which the operative is working (and hence the periods of outside and inside work) are calculated and drawn at standard performance. In figure 75 no account has so far been taken of relaxation or other allowances: manual work has been calculated at standard pace and is thus shown in basic minutes. Machine-controlled time is of course shown in actual minutes, and so, using the 0-100 rating scale advocated in this book, basic minutes for manual work and actual minutes of machine operation are comparable and can be drawn to the same scale.
Time Standards for Machine Working

When computing unoccupied time it is first necessary that the working time shall have been calculated at standard performance, that is at standard pace and with proper allowance made for relaxation (the calculation of relaxation allowances is discussed later). In special circumstances the work elements associated with machine operation may be calculated at some defined rate other than standard, but we shall not be concerned with these in this book.

The diagram in figure 75 looks not unlike a schematic representation of a bicycle pump, and indeed work study men often refer colloquially to such drawings as "pump diagrams". When seeking to improve the method the work study man follows two main approaches: he tries if he can to "push the handle down into the pump"—that is, to arrange for some of the manual elements which are being performed outside the machine-controlled time to be carried out as inside work, thus shortening the work cycle (this has been done in the present example). And he gives close attention to "shrinking the pump"—making the machine-controlled time as short as possible by ensuring that the machine is being used to best advantage, at correct speeds and feeds, and using cutting tools which are correctly ground and made of the best type of cutting steel for the sort of work in hand, so that the machine running time is machine running time at standard.

4. COMPUTATION OF RELAXATION ALLOWANCES

When computing relaxation allowances for wholly manual operations it is convenient to combine together the personal needs allowance and the basic minimum fatigue allowance into a single constant, adding any variable addition to the basic fatigue allowance separately. For a great many jobs the combined constant portion of relaxation allowance is all that is necessary, and for many more the addition of the increment for working standing up produces a higher figure which can also be applied as a constant to calculate the allowance required.

This convenient practice cannot be adopted when dealing with restricted work, however. It is essential that the personal needs allowance and the fatigue allowance be computed quite separately. The reason for this is that the personal needs allowance has to be calculated not merely on the elements of manual work contained in the work cycle but on the whole of the cycle time, including the machine-controlled time, for the percentage figures for the allowance are based on time spent at the workplace rather than on the time actually devoted to work. Fatigue allowance, on the other hand, is necessitated by work and is calculated on the basic minutes of work actually performed.

Apart from this difference, relaxation allowance is computed in exactly the same way as was described in the last chapter.

This is not the end of the matter, however. Once the allowance has been calculated, it is next necessary to consider whether the operative can be expected
to take any or all of it within the work cycle or whether it must be added to the sum of outside work plus machine-controlled time to derive the true cycle time.

If the work cycle is a very long one, and there are lengthy periods of unoccupied time within it, it may be possible in certain circumstances for the whole of the personal needs allowance and the fatigue allowance to be taken within the cycle, during the time when the operative is not working. Such periods can only be considered adequate for personal needs allowance if they are long enough (say ten or fifteen minutes), if they occur in an unbroken stretch, and if it is possible for the operative to leave his machine unattended meanwhile. This may be done safely if the machine has an auto-stop mechanism and needs no attention whatever while it is running; alternatively, when groups of operatives work together it is sometimes possible to arrange for a neighbour to use some of his own unoccupied time in giving attention to the absent worker’s machine. In textile factories and in other industries in which the processing machinery is run continuously, perhaps 24 hours a day, it is common to provide “floating” workers who can fill in at work stations for odd moments and can help to keep the machines running during short meal breaks if these are taken at staggered times.

The much more usual case, however, and especially with cycles of short duration, is that the whole of the personal needs allowance must be taken outside the working cycle. In the milling example which has been illustrated above and which has a cycle time of 1.36 min, it would obviously be impossible for the operative to take any of his personal needs allowance within the cycle.

Fatigue allowance is a rather different matter. Quite short periods of unoccupied time can be utilised for recovery from fatigue, provided that the operative can truly relax during them and is not required to be constantly on the alert or to give attention to the machine during them, and that he has a seat nearby. It is generally considered that any period of half a minute or less is too short to be counted as available for relaxation, and that any unbroken period of one-and-a-half minutes or longer can be reckoned as fully available for recovery from fatigue. Periods of 0.50 min or less would thus be disregarded. For periods of between 0.50 and 1.50 min it is common to compute the time which may be considered as effectively available for relaxation by deducting 0.50 min from the actual length of the period and multiplying the result by 1.5. The effect of applying this calculation to four periods between 0.50 and 1.50 min is shown below—

<table>
<thead>
<tr>
<th>Actual unbroken period of unoccupied time</th>
<th>Time calculated as effectively available for recovery from fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50 min</td>
<td>nil</td>
</tr>
<tr>
<td>1.00</td>
<td>0.75 min</td>
</tr>
<tr>
<td>1.25</td>
<td>1.12</td>
</tr>
<tr>
<td>1.50</td>
<td>1.50</td>
</tr>
</tbody>
</table>

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In the milling machine example the length of time during which the operative was not working was only 0.24 min, which is too short to be taken into account for relaxation. In this particular example the inside work was performed in one unbroken stretch of 0.56 min, but it is quite common in machine operations for the worker to have to make adjustments or attend to the machine at intervals, or perhaps carry out manual elements on other workpieces from time to time while the machine is working, so that within the machine-controlled time there will be separated periods of inside work and unoccupied time.

The length of the cycle and the manner in which any inside work occurs thus both affect the way in which relaxation allowance must be treated. Four cases can be distinguished:

1. All the personal needs allowance and all the fatigue allowance must both be taken outside the working cycle.
2. The personal needs allowance must be taken outside the cycle, but all the fatigue allowance can be taken within it.
3. The personal needs allowance and some of the fatigue allowance must be taken outside the cycle, but the rest of the fatigue allowance can be taken within it.
4. All the personal needs allowance and all the fatigue allowance can be taken within the working cycle.

The effect of these four cases for four different operation sequences is illustrated in figure 76. All the four operations have the following characteristics in common:

- Machine-controlled time: 15 min
- Outside work: 10 basic min
- Inside work: 5 basic min
- Personal needs allowance: 5 per cent. of outside work plus machine-controlled time: 1.25 min
- Fatigue allowance: 10 per cent. of total basic minutes: 1.50 min

In case 3 there is a period of one minute within the machine-controlled time when the operative is not working and, by using the method of calculation described above, 0.75 min of this is considered to be available for recovery from fatigue, so that the remaining 0.75 min of the fatigue allowance has to be taken outside the working cycle. In case 4 the assumption has been made that a neighbouring worker could attend to the operation if it should be necessary for the operative to leave his work station for longer than the ten minutes of non-working time available during the machine element.
It will be seen that the over-all cycle time differs in each of the four cases, so that the number of units of output which could be expected over an eight-hour day also differs:

<table>
<thead>
<tr>
<th>Case</th>
<th>Over-all cycle time (min)</th>
<th>Anticipated daily output (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>27.75</td>
<td>17.3 say, 17</td>
</tr>
<tr>
<td>Case 2</td>
<td>26.25</td>
<td>18.3 say, 18</td>
</tr>
<tr>
<td>Case 3</td>
<td>27.00</td>
<td>17.7 with overtime, 18</td>
</tr>
<tr>
<td>Case 4</td>
<td>25.00</td>
<td>19.2 say, 19</td>
</tr>
</tbody>
</table>
The over-all cycle time is the total time in which the job should be completed at standard performance, and is made up (in the case of operations of the types so far discussed) of outside work at standard pace, machine-controlled time, and any portion of the relaxation allowance which has to be allowed outside the machine-controlled time. If there are no other allowances to be taken into account (e.g. contingency allowance), and an allowance is made for unoccupied time in actual minutes, the over-all cycle time will be numerically equal to the standard time for the operation.

5. UNOCCUPIED TIME ALLOWANCE

In the construction of scale diagrams representing restricted work cycles, such as those illustrated in figures 75 and 76, it is usual to show all the manual elements at the times they would take if performed at standard pace. This is convenient for method study, and for the calculations needed to determine relaxation allowances and how they may properly be allocated, after which over-all cycle times and hence anticipated outputs may be computed.

The next step is to calculate the total period of any unoccupied time, in actual minutes. For operations of the types discussed the unoccupied time is computed by subtracting from the machine-controlled time the sum of all periods of inside work, in basic minutes, plus any part of the relaxation allowances which may be taken within the machine-controlled time. It should be particularly noted that for the calculation of unoccupied time all work elements must be computed at standard pace.

Standard times for jobs or operations are computed on the basis of the work done by operatives—that is the manual work content of the job—not that done by machines. For a job made up solely of manual elements (unrestricted work) the standard time is essentially a measure of the work which the job contains. With restricted work, however, the standard time expresses something more than this. It will be recalled that the definition of standard time is as follows:

**Standard time is the total time in which a job should be completed at standard performance.**

In order to compile the standard time for a restricted operation, therefore, it is not sufficient simply to compute the work content (inclusive of relaxation allowances, and the work portion of any contingency allowance considered appropriate), adding to this perhaps some small further contingency allowance for delays. It is necessary to add an allowance for any unavoidable unoccupied time which may be experienced during the machine- (or process-) controlled time.
Unoccupied time allowance is an allowance made to a worker when there is unoccupied time during machine- or process-controlled time.

Before the allowance is made the work study man must first have satisfied himself that the unoccupied time is truly unavoidable, and cannot be reduced further by method improvement or by a reallocation of work or machines. It has been noted earlier that it may be sound management practice to accept a certain amount of unoccupied time if by so doing costly machines can be kept more fully employed, for in restricted work machine utilisation is often more important than labour productivity.

Unoccupied time allowance is made in actual minutes.

Payment for Unoccupied Time

When standard times are used as a basis for payment-by-results schemes, the inclusion of unoccupied time allowances in standard times for restricted work may give rise to payment anomalies, unless special measures are taken to deal with the problems which arise.

The sort of difficulty which can occur is most easily seen by considering an example. Let us assume that in a given enterprise there are three jobs, for each of which the standard time has been computed as 100 minutes. The first job is made up wholly of manual elements. The other two are both restricted operations and for both the standard times include allowances for unoccupied time, say 15 minutes in one case, and 45 minutes in the other.

If all three workers perform the manual elements of their tasks at standard pace and all take exactly the allotted relaxation periods, then all three jobs will be completed in the same time, 100 minutes. But the operative on unrestricted work will have been working all the time (except, of course, for the relaxation period) while the other two will have been idle for 15 and 45 minutes respectively. If payment is made for unoccupied time at the same rate as that for working time the more heavily loaded workers will soon become discontented; jobs will become known as “good” jobs or “bad” jobs according to the amount of unoccupied time they contain, and there will be reluctance to undertake tasks with the higher work contents.

The way in which this is usually dealt with is not to make any modification to the standard times but to establish different rates of payment for work and for idle time. To enable this to be done, it is usual to express standard times not only as totals but also as work credits plus idle time credits (or in similar terms).
Thus in the example cited above the standard time, 100 min in each instance, would be shown as made up of 100, 85 and 55 work credits plus 0, 15 and 45 idle time credits respectively. It may be noted in passing that idle time credits included in a standard time may be allocated for reasons other than unoccupied time as discussed above. Idle time credits may be necessary on occasion to compensate for delays caused by waiting for work or for instructions, or by machine breakdowns.

The scheme to be adopted to make differential payments for work and for idle time in a particular enterprise is properly a matter of wages administration, rather than of time study practice, and is thus outside the scope of this introductory book. It may be noted, however, that any such scheme should be simple to understand, so that the workers may readily comprehend why jobs taking the same time to complete attract different payments. The scheme should be negotiated and agreed with the workers' representatives before it is applied. In a typical scheme idle time credits amounting in total to less than 5 per cent. of the work credits may be paid for at the same rate as work credits: idle time amounting to 40 per cent. or more of the work credits at three-quarters of the rate for working; and idle times between 5 per cent. and 40 per cent. at varying rates in between.

The scheme which will be most appropriate for a particular organisation will depend on local circumstances, and especially on whether jobs with large amounts of unoccupied time are exceptional or common. Sometimes variable rates which have to be read off a curve are adopted, but in general a linear relationship is to be preferred, and always one which is simple.

The time study man is concerned primarily with measuring the amount of time which is necessary to complete a job or operation, rather than with whatever arrangements are agreed for making payment for that time. It is common in industrial wage agreements to take account of different levels of skill required for different operations by paying differing rates per minute or per hour of work. Other factors may also be taken into account in setting payment rates. None of these matters will affect the computation of any unoccupied time allowance which may be necessary to compile the standard time for a job. The time allowance will be in minutes or hours: payment for those minutes or hours will be negotiable quite separately.

In the scheme instanced above relatively long periods of unoccupied time are paid for at lower rates than those paid for working, but in some circumstances it may be appropriate to pay for both working time and unoccupied time at very high rates indeed, in which case the payment actually made to a particular operative for a minute of unoccupied time may be greater than that paid to another for a minute spent working.

An example is the final machining of a shaft for a turbine-driven electricity generating set. Such a shaft may be several metres in length, and by the time that
the last stages of machining are undertaken the component will represent a large investment, in terms of both labour and the costly materials of which it is made. A faulty cut may result in a diameter becoming undersize, with the consequence that the whole shaft would have to be scrapped. The operator is thus burdened with a very heavy responsibility, although the actual operation itself is not particularly complex. Because of this responsibility the rates paid to the operator, both for working and for any necessarily unoccupied time, may be higher than those for the general run of turning operations. Similar “key” operations or tasks occur in many industries.

6. MULTIPLE MACHINE WORK

Multiple machine work is work which requires the worker to attend two or more machines (of similar or different kinds) running simultaneously.

In Section 3 the simple case of one man and one machine was examined. Frequently, however, workers are called upon to look after more than one machine—perhaps many machines—and this poses special problems in time study work. A common example is the weaving shed in a textile mill, where a worker may attend anything from four to 40 looms (perhaps even more), depending on the type of loom installed and the characteristics of the cloth being woven. Similar circumstances are often encountered in engineering industries, for example when workers operate batteries of screwmaking or coil-winding machines. It is usual in work situations of this sort for the machines to be equipped with automatic cut-out devices which bring them to a standstill when their tasks are completed or when breaks or malfunctioning occur.

Tasks of this sort are all examples of restricted work, for the output of the worker may be limited by factors outside his control. So too are team operations, whether the team of workers is concerned with the operation of a single machine—as sometimes occurs in drop-forging—with several machines—a frequent occurrence in textile operations—or indeed with no machines at all, for restrictions can be imposed by lack of balance in the amounts of manual work which have to be performed by different members of the team.

Load Factor

The load factor is the proportion of the over-all cycle time required by the worker to carry out the necessary work at standard performance, during a machine- or process-controlled cycle.
The load factor is sometimes known by the alternative terms “extent occupied”, or “work load”. In the simplest case of one man operating one machine, as illustrated in figures 75 and 76, if the over-all cycle time is 10 min and the amount of manual work contained within the cycle totals only 1 standard minute, the load factor would be one-tenth, or 10 per cent.

The reciprocal of the load factor therefore indicates the number of machines which the worker could theoretically tend: in this example ten machines. In practice other factors have to be taken into account, so that the load factor can be taken only as a very rough first indication of the number of machines which can usefully be allocated to a worker. It does sometimes occur that the work elements consist solely of unloading finished pièces from machines which have stopped automatically, loading fresh pieces and restarting the machines, and if all the machines are alike and are working on exactly similar pieces then the ideal sequence of operation may be achievable, with the worker able to operate the number of machines indicated by the reciprocal of the load factor. Much more commonly, however, differences occur in the machines or in the work, and frequently attention has to be given to the machines while they are running, with the result that the worker cannot always get to a machine at the exact moment when attention is needed. The delays which then occur are known as machine interference.

**Machine Interference**

Machine interference is the queuing of machines (or processes) for attention—e.g. when one worker is responsible for attending to more than one machine. Similar circumstances arise in team work where random delays at any point may affect the output of the team.

When studying multiple machine working or team working (with or without machines) the work study man has first to examine the methods of working with the object of devising a sequence of operation which will result in the best balance and thus the least interference, and then to use time study techniques to measure the amount of interference which will occur even when the best sequence has been determined. These tasks may sometimes be extremely complicated. They often call for the use of specialised methods which are beyond the scope of this book.1

If there are only a few workers in the team, or if one or two workers are operating only a few machines between them, simpler methods will suffice. Operation sequences can be plotted and examined on multiple activity charts (described in

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1 Some references to specialised texts will be found in Appendix 8.
Chapter 10), supplemented by cycle diagrams similar to those shown in figures 75 and 76. The diagrams for each machine are drawn one below the other, to the same time scale. A simple example, that of an operator working three machines, is shown in figure 77.

![Figure 77. Machine Interference](image)

In this example there is no inside work, so that once a machine has been started the operator can turn his attention to another. The sequence in which he does so is indicated by the small vertical arrows. It will be seen that with this particular routine, machine C is operated without any delays occurring, but the result of doing this is that both machine A and machine B switch themselves off at the end of their respective operations and then have to wait a while before the operator can get to them. The interference is indicated on the cycle diagrams for machines A and B by grey arcs.

**Interference Allowance**

An interference allowance is an allowance of time for production unavoidably lost through synchronisation of stoppages on two or more machines (or processes) attended by one worker. Similar circumstances arise in team work.

By extending the methods so far described, using the same charting conventions and principles, it is possible to establish work sequences and to calculate interference for a fairly wide range of multiple machine operations, including many which will be met with in the engineering and allied industries, and especially those in which machine stoppages occur in regular, predictable fashion rather than at random. In coil-winding, for example, the winding machines switch themselves off when the coil is completed, and contingencies (such as wire breaks) are rare.
For these simpler forms of multiple machine operation, when an operative has only a few machines to look after and the work being done is of a cyclic nature, with definite beginnings and ends of the work cycles, standard times may be calculated and expressed exactly as for unrestricted work; that is as so many standard minutes (or hours) per piece, per job or per operation. This is quite common in engineering machine shop operations, especially when workers operate several machines in sequence. For these situations standard times are compiled as described earlier in this book, on the basis of the work content for each job or operation. There is no need to consider machine interference when compiling the standard times, though it may be necessary to take this into account when making output predictions and other production control calculations. It will be necessary, however, to provide allowances in the standard times for any unavoidable unoccupied time which may be experienced as a result of working with the machines, and this too may be done as described above.

When output is continuous rather than cyclic, and especially in process industries, it is more usual to establish standard times for some convenient volume, weight, or length of output, rather than per piece or per operation. Thus in weaving the standard times may be compiled and expressed as so many standard minutes per 100 metres of cloth woven. When this is done the focus is shifted from the amount of manual work contained in the operation to the output which may be expected from the machines, though output calculations must of course take into account the quantity of manual work involved in tending the machines. Unoccupied time is of interest, and almost always has to be determined, not for the purpose of making an allowance in the standard time but rather as an indication of the number of machines which a worker can attend. For the calculation of standard times the allowance which has to be taken into account is interference allowance—the times during which some of the machines will be stopped while waiting for the operator to get to them.

A case in point is that of a weaver looking after a set of looms. Stoppages in the weaving operation depend upon many circumstances. The strength of the yarn, and hence the frequency of breakages, is influenced by the way the materials forming the warp and weft have been prepared, and also by the temperature and humidity within the weaving shed, both of which may change markedly from time to time during a shift. The state of maintenance of the looms also affects stoppages, while the speed and skill of the weaver have a further influence, for a skilled operative can often prevent stoppages by anticipating trouble and taking preventive action.

In circumstances such as these it is necessary to evaluate unoccupied time (for work loading and team balancing) and interference (for compiling standard times) by extended studies on the shop floor, covering all the different working conditions and all the different counts of yarn (in weaving) or different materials.
which have to be worked on. Studies may have to continue for days, weeks, or sometimes extend over several months. The work measurement technique known as **activity sampling** (described in Chapter 21) is the appropriate one to use for this purpose, and was originally developed expressly for textile operations. It is much more economical than time study, which would be much too long-winded and detailed for this type of observation in any but the smallest shops. Using activity sampling, for example, a studyman in a weaving shed can record all the information needed while observing the operation of 10 or 12 looms, which would be impossible with ordinary time study practice.

In an introductory book of this nature it is not possible to cover in detail the specialised methods which are adopted in advanced work study practice to evaluate interference and compute interference allowances in complex multiple machine situations. For the most part these methods are based on statistical procedures and probability theory, and are intended to permit reliable predictions to be made without recourse to either time study or activity sampling. For this purpose a number of formulae, curves and sets of tables have been compiled to assist in the determination of interference, and hence probable output, for various worker/machine combinations. The systems, if used with care, offer the prospect of considerable economy of study time in certain specialised, but complex, multiple machine and teamwork situations. It is essential, however, that any predictions made on the basis of formulae and tables should be validated by direct study at the workplace, so that full account may be taken of local working conditions.

The time study methods described earlier in this chapter, together with activity sampling (as described in Chapter 21) will usually be found adequate for the computation of reliable time standards for the majority of the machine working situations likely to be encountered in general industrial practice. Those readers who are faced with the task of determining standards for complex multiple machine operations may find it useful to consult more advanced texts, some of which are listed in Appendix 8. It is recommended, however, that the more specialised methods should not be attempted until the work study man has had sufficient experience of both time study and activity sampling to be sure that he can use these techniques to verify any statistical predictions made.

* * *

In the next chapter an example of a fully worked time study is shown. The study is one taken on the operation of milling a casting, which was the subject charted on a multiple activity chart in Chapter 10, and for which a cycle diagram appears in Section 3 of the present chapter.
CHAPTER 19

EXAMPLE OF A TIME STUDY

In discussing the making of a time study throughout the last four chapters reference has been made to the example based on the milling of a casting which was the subject of the multiple activity chart described in Chapter 10. The complete time study is shown in this chapter. A careful study of the forms shown in the illustrations should enable the reader to follow in detail the processes by which a time study is worked up and a standard time is compiled.

This particular example has been chosen because—

1. it is simple;
2. it has already been the subject of a method study;
3. it includes both manual and machine elements;
4. it is typical of the sort of operations met everywhere in the engineering industry and in other industries using machines and semi-automatic processes.
Example of a Time Study

The forms used are simple general-purpose forms such as those illustrated in Chapter 14. Although all the entries made on the forms will be handwritten it is usual to space the lines for use with a typewriter because occasions may arise on which it is required to produce fair copies of original studies for discussion or circulation.

The study illustrated in this chapter was not the first one on this operation. The elements and break points were defined at the time the method study was undertaken, and were then set out on a card prepared and filed by the work study department. This is a useful practice when it is expected that an operation will be studied several times, perhaps by different studymen. It ensures that the recordings made on all the studies are comparable. The elements and break points are shown in figure 78.

Although the example which has been studied in detail is a simple one for a manufacturing industry, exactly the same procedure is carried out for non-manufacturing operations or for any other work which is time-studied for the purpose of setting time standards. Entirely manual operations, such as assembly, would be treated in exactly the same way.
FIGURE 78. CARD DETAILING ELEMENTS AND BREAK POINTS

Card No. 1264

<table>
<thead>
<tr>
<th>Part:</th>
<th>B.239 Gear case.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material:</td>
<td>ISS 2 Cast iron.</td>
</tr>
<tr>
<td>Operation:</td>
<td>Finish-mill second face.</td>
</tr>
<tr>
<td>Machine:</td>
<td>No. 4 Cincinnati vertical miller.</td>
</tr>
<tr>
<td>Fixture:</td>
<td>F.239.</td>
</tr>
<tr>
<td>Cutter:</td>
<td>25 cm. T.L.F.</td>
</tr>
<tr>
<td>Gauge:</td>
<td>239/7. Surface plate.</td>
</tr>
</tbody>
</table>

**Elements and Break Points**

A. Pick up casting, locate in fixture, lock two nuts, set guard, start machine and auto feed. Depth of cut 2.5 mm. Speed 80 r.p.m. Feed 40 cm/min.  
   *Break point:* Machine commences cut.

B. Hold casting, break milled edge with file, clean with compressed air.  
   *Break point:* Air gun dropped onto hook.

C. Move depth gauge to casting, check machined surface, move gauge away.  
   *Break point:* Left hand releases gauge.

D. Pick up machined casting, carry to finished parts box and place aside, pick up next part and position on machine table.  
   *Break point:* Casting hits table.

E. Wait for machine to complete cut.  
   *Break point:* Machine ceases to cut.

F. Stop machine, return table, open guard, unlock fixture, remove machined casting and place on surface plate.  
   *Break point:* Casting hits surface plate.

G. Clear swarf from machine table with compressed air.  
   *Break point:* Air gun dropped onto hook.

*Note:* Elements B, C and D are inside work, and are performed on a casting which has already been machined while the milling machine is cutting the next casting. Element D includes bringing up into a handy position a fresh casting which will be machined after the one now in the machine.
FIGURE 79. SKETCH OF WORKPLACE LAYOUT AND PART
(On reverse of time study top sheet)

A sketch of the workplace layout is generally more necessary in assembly or materials handling studies than in studies of machine shop operations where workplaces are likely to be the same for all jobs on the machines. The part should be sketched showing the surfaces machined and, in the case of capstan lathes, tool set-ups should be included. This is best done on squared paper and may be on the back of the time study top sheet if desired in order to keep all the information relevant to the study on one sheet. To facilitate sketching, the reverse of the top sheet is often printed as squared paper.
Example of a Time Study

(a) Sketch of gear-case casting showing surface to be machined and dimension

(b) Layout of workplace
FIGURE 80. TIME STUDY TOP SHEET

All the information in the heading block at the top of the form (except time off and elapsed time) was entered before the watch was started and study commenced.

If the study had been the first one on this operation the studyman would have entered in full the element descriptions and break points in the column headed “Element description” on the left-hand side of the page. In the present instance this was not necessary as the card shown in figure 78 listed all the detail. It is necessary that the studyman should watch a few cycles of the operation to make sure that the listed method is being used, and to familiarise himself with the break points, before starting to record. The elements were identified simply by the letters A to G.

At exactly 9.47 a.m. by the study office clock (or the studyman’s wristwatch) the stopwatch was started. It ran for 1.72 min before element A of the first cycle started, so this time is entered at the beginning of the study as the “time before”. Since this was a study using cumulative timing the watch ran continuously throughout. When the study was broken off after observing 18 cycles the studyman allowed his stopwatch to run on until the study office clock reached the next full minute (at 10.25 a.m.), noted the “time after”, and stopped his stopwatch. These terminal entries will be found at the end of the recordings in figure 81.

The four columns used in cumulative timing are respectively “rating” (R.), “watch reading” (W.R.), “subtracted time” (S.T.) and “basic time” (B.T.). The placing of the rating column first is logical and encourages the observer to rate while the element is in progress and not to wait for the watch reading. If flyback timing had been used the W.R. column on the form would not be necessary.

Only the entries in the two columns headed R. and W.R. were made during observations at the workplace. The other two columns were completed in the study office after observations had been discontinued. In practice, the “rating” and “watch reading” entries would be made in pencil while those in the “subtracted time” and “basic time” columns would be made in ink or with a pencil of another colour from that used for the observations.

The studyman numbered the cycles observed, from 1 to 18, with ringed figures at the left of the “element description” column.

When entering watch readings there is no need to use decimal points. The first entry, time before, 172, indicates a time of 1.72 min. The next watch reading was made 1.95 min after the watch was started, but it is only necessary to enter 95. The third entry of 220 indicates that the reading was made at 2.20 min after starting; the entries then revert to two figures only until the next minute is passed. During cycle number 15 (recorded on figure 82) the total study time passed 30 min, which is the time taken by the hand on the small inner dial on the watch to complete one revolution. As the study continued into a further revolution of the small hand subsequent watch readings revert to 1 again. It will be seen that the recording against element F of cycle 15 was 106, which of course means 31.06 min after the watch was started.

Element E—“wait for machine to complete cut”—is not work, and was therefore not rated. It will be seen that there is no entry against this element in the basic time column.
## Example of a Time Study

### TIME STUDY TOP SHEET

**DEPARTMENT:** Machine Shop — Milling Section  
**STUDY No.:** 17  
**SHEET No.:** 1 of 5  
**OPERATION:** Finish-mill second face  
**M.S. No.:** 9  
**PLANT/MACHINE:** Cincinnati No.4 vertical miller No.26  
**TOOLS AND GAUGES:** Fixture F 239: Cutter 25 cm T.L.F.  
Gauge 239/7: Surface plate  
**TIME ON:** 9.47 a.m.  
**TIME OFF:** 10.25 a.m.  
**STUDIED BY:** M.N.  
**OPERATOR:** Ashraf  
**CLOCK No.:** 1234  
**DATE:** 4.5.66  
**CHECKED:** S.R.

**PRODUCT/PART:** B. 239 Gear Case  
**DWG. No.:** B. 239/1  
**ISS.:** 2  
**MATERIAL:** Cast iron  
**QUALITY:** As drawing  
**ELEMENT DESCRIPTION**

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</thead>
<tbody>
<tr>
<td><strong>Time before</strong></td>
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<td><strong>Elements &amp; B.P. C</strong></td>
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<tr>
<td>@</td>
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<td>25</td>
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</tbody>
</table>

418  
440
The recordings covered three sheets in all. Figure 81 shows the first of the two continuation sheets, and it will be seen that it is numbered in the top right-hand corner: Sheet No. 2 of 5. The analysis sheet and study summary sheet eventually completed the set of five sheets, all of which were stapled together after the study was worked up.

Besides the element ratings and timings, continuing as on the top sheet, two interruptions were recorded on this sheet: “Talk to foreman”, and “Break for tea”. Neither of these were rated, of course. The first was taken account of when considering contingencies, while the second was covered by the relaxation allowance made when the standard time for the operation was compiled.
### Example of a Time Study

**STUDY No.: 17**

<table>
<thead>
<tr>
<th>TIME STUDY CONTINUATION SHEET</th>
<th>SHEET No. 2 OF 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELEMENT DESCRIPTION</strong></td>
<td><strong>R.</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>A</td>
<td>105</td>
</tr>
<tr>
<td>B</td>
<td>115</td>
</tr>
<tr>
<td>C</td>
<td>95</td>
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<tr>
<td>D</td>
<td>85</td>
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<td>80</td>
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<td>Q</td>
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<td>W</td>
<td>G</td>
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<tr>
<td>X</td>
<td></td>
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<tr>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td></td>
</tr>
<tr>
<td><strong>Talk to foreman</strong></td>
<td>75</td>
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</tbody>
</table>

## Notes

- **A**
- **B**
- **C**
- **D**
- **E**
- **F**
- **G**
- **H**
- **I**
- **J**
- **K**
- **L**
- **M**
- **N**
- **O**
- **P**
- **Q**
- **R**
- **S**
- **T**
- **U**
- **V**
- **W**
- **X**
- **Y**
- **Z**

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Total:

- **631**

- **1203**
Example of a Time Study

FIGURE 82. SECOND CONTINUATION SHEET

The first entry on this sheet recorded another interruption—the patrol inspector, having checked three workpieces, drew the operator's attention to some feature of them and discussed them with him. The time taken to do this, like that recorded on the previous sheet against "Talk to foreman", was later entered as a contingency.

After cycle number 16 a fresh element of work occurred—helping the labourer to move boxes of work off and onto the truck. This was an occasional element, in contrast to elements A to G which were repetitive. The studyman rated and timed the element, and it will be noted that, since the element ran on for rather over a minute in all, the studyman made a rating and a watch reading at the end of each of the first two half-minutes, as well as during the last part of the element. This practice, which makes for greater accuracy, was referred to in Section 9 of Chapter 16.

Back in the study office after breaking off observations, the studyman first completed the "time off" and "elapsed time" entries in the heading block on the top sheet, and then set about calculating the subtracted times, by deducting each watch reading from the one which follows it and entering the result in the third column, headed S.T. It will be seen that he totalled these subtracted times at the foot of each page, and carried forward the subtotals to the sheet shown opposite, where they were added up to yield 35.20 min. When the time before and the time after were added to this figure the result was 38.00 min, which agreed with the elapsed time and thus afforded a check that the work of subtraction had been done correctly.

The next step was "extension"; multiplying each subtracted time by the percentage rating recorded against it to yield the basic time, entered in the fourth column. Extension is easily and quickly done with the aid of a slide rule. The calculation is made to the nearest second decimal place; that is, to the nearest one-hundredth of a minute. Thus 0.204 would be shown as 20, and 0.206 min as 21—which leaves the problem of what to do with 0.205. Evidently in this study office the standing rule was to take half-hundredths of a minute down rather than up, as can be seen by the entry against element G of cycle 15. Here, the rating was 105 and the subtracted time 10, so that the extension yields 0.105 min to three places. This has been shown as 10, the half-hundredth having been taken down. Other instances will be found in the study. Most study offices apply the reverse rule, taking middle times up.
## Example of a Time Study

<table>
<thead>
<tr>
<th>STUDY No.: 17</th>
<th>TIME STUDY CONTINUATION SHEET</th>
<th>SHEET No.3 OF 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELEMENT DESCRIPTION</strong></td>
<td><strong>R.</strong></td>
<td><strong>W.R.</strong></td>
</tr>
<tr>
<td>Patrol inspector checks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 pieces: discuss</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>©</td>
<td>A</td>
<td>95</td>
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<td>95</td>
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<tr>
<td></td>
<td>G</td>
<td>85</td>
</tr>
<tr>
<td>Help labourer unload</td>
<td>85</td>
<td>320</td>
</tr>
<tr>
<td>boxes of new castings</td>
<td>95</td>
<td>70</td>
</tr>
<tr>
<td>and load finished work</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td>on truck (30 new + 30 fin. in boxes of 10)</td>
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<tr>
<td>©</td>
<td>A</td>
<td>100</td>
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</tbody>
</table>

Elapsed: 3800

| 680 |  |  |  |  |  |  |  |  |  |  |

339
Example of a Time Study

FIGURE 83. WORKING SHEET

The repetitive elements A, B, C, D, F and G were all constant elements, and selected basic times for them were obtained by averaging. As was noted in Chapter 14, study analyses take several forms and for this reason it is not usual to have specially printed sheets for them. Ordinary lined or squared paper serves very well, and when the time study top sheet has been printed on the reverse as squared paper (to facilitate sketching) it will do well enough to use the back side of a top sheet, entering at the top the study and sheet numbers. For a simple study the analysis is often made straight onto the study summary sheet, a few extra columns being ruled in the space headed “element description”.

Methods of obtaining the selected basic times are discussed in Chapter 17. In this instance inspection of the basic times tabulated under elements A, B, C, D, F and G showed no anomalies, and therefore no need to ring out “rogue” times. For each of these elements the basic times have been totalled, and the selected basic time was computed by dividing the total by the number of observations (18).

No figures were listed under element B, “Wait for machine to complete cut”. This was unoccupied time, which was not rated in the study. The actual length of unoccupied time experienced in the various cycles observed depended on the speed with which the operator carried out the inside work which he performed on another casting while the machine was cutting automatically.

The time which the machine took to make the cut, while on automatic feed, did not vary from cycle to cycle because it was determined by the rate of feed at which the machine was set and the length of cut to be made. It could thus be calculated quite easily. In this study the machine-controlled time started at the end of element A and ended with the conclusion of element E. The machine-controlled time can therefore be obtained from the study sheets by subtracting the watch reading against element A from that against E. This has been done, the results being tabulated under “MCT” at the right-hand side of the working sheet. These times are of course actual minutes, not basic times.

It will be seen that two of the MCT entries have been ringed out. The studyman did not enter any explanation of unusual events on his record, and inspection of the observations for the cycles in which these rogue times occurred does not provide any conclusive explanation. Possibly the explanation for the shorter time is to be found in the fact that the operator can start the cut on hand-feed before locking on the auto-feed, and on this occasion, unnoticed by the studyman, he spent longer on hand-feed than usual. The explanation for the longer time in cycle 17 may be that the operator failed to switch the machine off quite as quickly as usual on this occasion, and again this escaped notice. The two ringed times were excluded from the total of 13.05 actual min for the machine-controlled times, so that this total was divided by 16 instead of 18 to derive the average MCT of .816.

Element E, the unoccupied time, was dealt with by subtracting the total of the selected basic times for elements B, C and D, the inside work elements, from the average MCT. The resulting figure for the average unoccupied time was .257 min.

At this stage in the calculations it is usual to make use of three decimal places for the selected basic times, and to retain the third place on the study summary sheet and the analysis of studies sheet.
Example of a Time Stud.

**Study No. 17**

**WORKING SHEET**

<table>
<thead>
<tr>
<th>Element:</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>MCT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Basic times)</td>
<td></td>
<td></td>
<td></td>
<td>(Actual minutes)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
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<td>25</td>
<td>25</td>
<td>12</td>
<td>19</td>
<td>25</td>
<td>09</td>
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<td>12</td>
<td>18</td>
<td>26</td>
<td>10</td>
<td>81</td>
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<tr>
<td>3</td>
<td>26</td>
<td>26</td>
<td>12</td>
<td>20</td>
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<td>7</td>
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<td>12</td>
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<td>28</td>
<td>10</td>
<td>81</td>
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<td>19</td>
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<tr>
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<td>29</td>
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<td>19</td>
<td>25</td>
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<td>11</td>
<td>82</td>
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<td>26</td>
<td>25</td>
<td>13</td>
<td>19</td>
<td>26</td>
<td>10</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>26</td>
<td>24</td>
<td>13</td>
<td>20</td>
<td>26</td>
<td>10</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>26</td>
<td>24</td>
<td>13</td>
<td>18</td>
<td>26</td>
<td>11</td>
<td>81</td>
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<td>17</td>
<td>27</td>
<td>27</td>
<td>13</td>
<td>19</td>
<td>25</td>
<td>10</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>27</td>
<td>25</td>
<td>12</td>
<td>19</td>
<td>25</td>
<td>11</td>
<td>81</td>
<td></td>
</tr>
</tbody>
</table>

| Totals    | 4.69| 4.52| 2.20| 3.35| 4.57| 1.84| 13.05 |
| Occasions | 18   | 18   | 18   | 18   | 18   | 18   | 16    |
| Average   | .261 | .251 | .122 | .186 | .254 | .102 | .816  |

MCT = .816
B + C + D = .559
Element E (unoccupied) = .257

Actual minutes
Basic minutes
Example of a Time Study

FIGURE 84. STUDY SUMMARY SHEET

The study summary sheet, when completed, was stapled on top of the other four study sheets and was eventually filed with them. The sheets which have been used for recording observations at the workplace often become somewhat dirty as a result of the conditions in which they have to be used and, because of the speed with which the observations have to be written down, frequently exhibit many abbreviations and perhaps hurried writing which is difficult for anyone except the studyman himself to read. The study summary sheet therefore not only presents concisely all the results obtained from the study but also records in the heading block, in ink and neatly written, all the information about the operation which was originally entered on the time study top sheet.

The repetitive elements A to G, excluding E, were entered first, and it has been noted that three of these were inside work and the other three outside work. The entries in the column headed B.T. are the basic times per occasion, and were taken from the working sheet shown in figure 83. For each of these elements the frequency of occurrence is shown as 1/1, indicating that each occurred once in every cycle of the operation. The times calculated for the machine element, and hence the unoccupied time (element E) are shown below. The column headed Obs. shows the number of observations of the element which have been taken into account in deriving selected basic times. This information will be carried to the analysis of studies sheet where it will be of use when the final selected basic times are derived for the compilation of the standard time.

Under the heading “Occasional elements and contingencies” is shown the basic time for the element of helping the labourer to load and unload boxes of castings. It is noted that this element was observed once only, and that its frequency ought to be 1/30 since 3 boxes of 10 fresh castings were brought, and 3 boxes of finished castings loaded. The other two non-repetitive occurrences observed were “Talk to foreman”, and “Inspector checks three pieces and discusses”. Neither of these periods was rated, so the times are shown in actual minutes (a.m.).

Finally, the studyman recorded, in actual minutes, the amount of relaxation taken during the period of the study.

Basic times were entered to the third decimal place, and have been carried forward in this form to the analysis of studies sheet. It may be thought that this is a degree of refinement which is not warranted in view of the accuracy of the data on which the entries are based. There is a good reason for the practice, however. If it is eventually decided to make the final selection of basic times, on the analysis of studies sheet, by the process of averaging, each of the entries from this study will be multiplied by the corresponding number of observations to yield the total basic minutes observed for the element. The totals from all the studies taken on this operation will be added, and an average obtained by dividing by the aggregate number of observations. At that stage, when the whole chain of arithmetical calculations has been completed, the final selections will be expressed to the nearest second decimal place only, that is to the nearest one-hundredth of a minute.
## STUDY SUMMARY SHEET

**DEPARTMENT:** Machine Shop  
**SECTION:** Milling  
**STUDY No.:** 17  
**STUDY No.:** 5 OF 5  
**OPERATION:** Finish mill second face  
**M.S. No.:** 9  
**DATE:** 4/5/66  
**PLANT/MACHINE:** Cincinnati No. 4  
**Vertical Miller**  
**No.:** 26  
**25 cm T.L.F.**  
**Cutter**  
**TOOLs AND GAUGES:** Fixture F.239  
**Gauge 239/7 Surface plate**  
**PRODUCT/PART:** B. 239 Gear Case  
**No.:**  
**DATE:** 4/5/66  
**TIME OFF:** 10:25 a.m.  
**TIME ON:** 9:47  
**ELAPSED TIME:** 38.00  
**CHECK TIME:** 2.80  
**PRODUCT/PART:** 8.239 Gear Case  
**No.:**  
**DATE:** 4/5/66  
**TIME OFF:** 10:25 a.m.  
**TIME ON:** 9:47  
**ELAPSED TIME:** 38.00  
**CHECK TIME:** 2.80  
**PRODUCT/PART:** B. 239 Gear Case  
**No.:**  
**DATE:** 4/5/66  
**TIME OFF:** 10:25 a.m.  
**TIME ON:** 9:47  
**ELAPSED TIME:** 38.00  
**CHECK TIME:** 2.80  
**OPERATOR:** Ashraf, C.A.  
**M/F**  
**CLOCK No.:** 1234  

### Sketch and notes on back of sheet 1

<table>
<thead>
<tr>
<th>El. No.</th>
<th>ELEMENT DESCRIPTION</th>
<th>B.T.</th>
<th>F.</th>
<th>Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Repetitive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside work</td>
<td></td>
<td>0.261</td>
<td>1/1</td>
<td>18</td>
</tr>
<tr>
<td>Inside work</td>
<td></td>
<td>0.251</td>
<td>1/1</td>
<td>18</td>
</tr>
<tr>
<td>C</td>
<td>As card No. 1264</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside work</td>
<td></td>
<td>0.122</td>
<td>1/1</td>
<td>18</td>
</tr>
<tr>
<td>Outside work</td>
<td></td>
<td>0.186</td>
<td>1/1</td>
<td>18</td>
</tr>
<tr>
<td>F</td>
<td>Outside work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside work</td>
<td></td>
<td>0.254</td>
<td>1/1</td>
<td>18</td>
</tr>
<tr>
<td>G</td>
<td>Inside work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside work</td>
<td></td>
<td>0.104</td>
<td>1/1</td>
<td>18</td>
</tr>
<tr>
<td>Machine element</td>
<td></td>
<td>0.816</td>
<td>1/1</td>
<td>16</td>
</tr>
<tr>
<td>Unoccupied time within M.C.T.</td>
<td></td>
<td>0.257</td>
<td>1/1</td>
<td>18</td>
</tr>
</tbody>
</table>

### Occasional elements and contingencies

- Help unload boxes of new castings and load boxes of finished castings to truck.  
  - (outside work)  
  - 1.100 1/18 obs.  
  - Freq. 1/30 castings (Boxes hold 10 castings)
- Talk to foreman (O.W.) (a.m.)  
  - 0.400 1/18 obs.
- Inspector checks 3 pieces and discusses (a.m.)  
  - 1.020 1/18 obs.  
  - (O.W.)

### Relaxation time (a.m.)

- 6.120
Example of a Time Study

FIGURE 85. EXTRACT FROM THE ANALYSIS OF STUDIES SHEET

As each time study on the operation was worked up and summarised the entries from the study summary sheet were transferred onto an analysis of studies sheet of the type illustrated in figure 64. These sheets are often printed onto paper of double foolscap size or larger, so only a portion of the whole sheet is reproduced opposite.

It will be seen that five studies were made in all on this operation, a total of 92 cycles being observed. The work of three different operators was studied, by four different studymen. Standard times for regular machine shop operations are usually compiled from "synthetic data" (see Chapter 21), and when a considerable body of data has been built up it is often possible to derive accurate time standards with fewer studies, or by observing a smaller number of cycles of the operation.

Inspection of the study results for the elements A, B, C, D, F and G indicated normal consistency, with no reading suggesting a need for further investigation. The work of proceeding to the final selected basic times for the elements was therefore undertaken next. The selection was made by taking the weighted average for each element. All the repetitive elements were constant elements, so there was no need for graphical presentation. In the first of the four columns in the block at the right-hand side of the sheet the total basic time was entered against each element. Dividing these totals by 92, the aggregate number of cycles, yielded the figures for basic minutes per occasion, entered in the next column. These are now shown to the second decimal place only; that is, to the nearest one-hundredth of a minute.

The third column records the frequency of occurrence per cycle—for all the repetitive elements 1/1—and thus the entries in the last column, which show the basic minutes per cycle, are for this operation the same as those in the second column of the right-hand block. The unoccupied time, element E, has been arrived at in the same manner as on the study summary, by deducting the sum of the inside work basic minutes from the machine-controlled time. In the general case the unoccupied time would not be evaluated until after relaxation allowance had been added to the work elements, but in this instance, as is indicated when discussing these allowances on the next page, there was no need for such a refinement.

The occasional element "Help labourer" was observed on three occasions only, in three different studies. Since it is known that the truck carries 3 boxes each containing 10 castings, it is clear that the frequency with which this element will occur is once every 30 castings, or cycles. The average basic time per occasion was therefore divided by 30 to yield the basic time per cycle of .04 min.

"Talk to foreman" was dealt with by dividing the total time observed by the 92 cycles observed, giving a time of .01 min per cycle. The "Inspector checks" element was treated similarly, though in this instance as it was learned from the foreman that the inspector's duty was to check 3 castings in every 100 the frequency has been taken as 1/100. These two very small periods of time, both entered in actual minutes, were eventually considered to be best dealt with as contingencies and were covered by the contingency allowance given.
### Example of a Time Study

<table>
<thead>
<tr>
<th>Study No.:</th>
<th>3</th>
<th>9</th>
<th>17</th>
<th>25</th>
<th>28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>27/4</td>
<td>1/5</td>
<td>4/5</td>
<td>7/5</td>
<td>11/5</td>
</tr>
<tr>
<td>Operative:</td>
<td>CAA</td>
<td>TBN</td>
<td>CAA</td>
<td>TBN</td>
<td>CRW</td>
</tr>
<tr>
<td>Clock No.:</td>
<td>1234</td>
<td>1547</td>
<td>1234</td>
<td>1547</td>
<td>1846</td>
</tr>
<tr>
<td>Machine No.:</td>
<td>26</td>
<td>34</td>
<td>26</td>
<td>127</td>
<td>71</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study taken by:</th>
<th>BDM</th>
<th>CEP</th>
<th>MN</th>
<th>DFS</th>
<th>BDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cycles studied:</td>
<td>15</td>
<td>26</td>
<td>18</td>
<td>13</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elements</th>
<th>Basic Time Per Occasion</th>
<th>B.T.</th>
<th>B.M.</th>
<th>B.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>P/U casting, locate, lock, set on</td>
<td>.276</td>
<td>.257</td>
<td>.261</td>
</tr>
<tr>
<td>B</td>
<td>Hold, break milled edge, clean</td>
<td>.240</td>
<td>.266</td>
<td>.251</td>
</tr>
<tr>
<td>C</td>
<td>Gauge</td>
<td>.114</td>
<td>.127</td>
<td>.122</td>
</tr>
<tr>
<td>D</td>
<td>Aside finished part, post new</td>
<td>.197</td>
<td>.196</td>
<td>.186</td>
</tr>
<tr>
<td>E</td>
<td>Wait m/c (actual minutes)</td>
<td>.264</td>
<td>.222</td>
<td>.257</td>
</tr>
<tr>
<td>F</td>
<td>Stop m/c, unlock, aside part</td>
<td>.271</td>
<td>.270</td>
<td>.254</td>
</tr>
<tr>
<td>G</td>
<td>Clear swarf</td>
<td>.096</td>
<td>.112</td>
<td>.104</td>
</tr>
</tbody>
</table>

### Machine-controlled time (actual minutes)
- .821 | .811 | .816 | .824 | .810 | 75.000 | .82 | 1/1 | .82 |

### Help labourer U/L and load boxes of castings
- 1.100 | 1.420 | 1.310 | 3.830 | 1.28 | 1/30 | .04 |

### Talk to foreman (actual minutes)
- 1.140 | .400 | .870 | 2.410 | .80 | 1/92 | .01 |

### Inspector checks, discuss (a.m.)
- 1.470 | 1.020 | 1.770 | 4.260 | 1.42 | 1/100 | .01 |
A form such as that shown in the figure is often used for the compilation of relaxation allowances. It provides a convenient way of ensuring that no item of relaxation allowance is omitted. The grouping of the allowances and the values are taken from table 12.

Since this is an example of restricted work the personal needs allowance and the fatigue allowance have been calculated separately. Both values are shown in the total column on the right-hand side of the form.

The only period of unoccupied time during the machine-controlled time totals 0.26 actual minutes. This was considered to be too short a period to be available for recovery from fatigue (see Section 4 of Chapter 18), so the whole of the relaxation allowance, both the personal needs part and the fatigue allowance, was given as additions to the outside work, and was added to the cycle time.

The personal needs allowance of 5 per cent. was calculated on the sum of the outside work plus the machine-controlled time. Fatigue allowance was calculated on the work elements only.

It will be seen from the table on page 349 that the total relaxation allowance amounted to 0.17 min. This is less than the period of unoccupied time, 0.26 min, but is nevertheless to be added outside the machine-controlled time as periods of half a minute or less of unoccupied time are ignored for fatigue allowance purposes.
## Example of a Time Study

### RELAXATION ALLOWANCE

**DEPARTMENT:** Machine Shop  
**PRODUCT:** B.239 Gear Case  
**WEIGHT:** 6.8 kg each  
**OPERATION:** Finish-mill second face  
**WORKING CONDITIONS:** Good

<table>
<thead>
<tr>
<th>EL. No.</th>
<th>ELEMENT DESCRIPTION</th>
<th>PERSONAL NEEDS ALLOWANCE</th>
<th>BASIC FATIGUE ALLOWANCE</th>
<th>STANDING</th>
<th>ABNORMAL POSITION</th>
<th>USE OF FORCE</th>
<th>LIGHT CONDITIONS</th>
<th>ATMOSPHERIC CONDITIONS</th>
<th>VISUAL STRAIN</th>
<th>AURAL STRAIN</th>
<th>MENTAL STRAIN</th>
<th>MONOTONY: MENTAL</th>
<th>MONOTONY: PHYSICAL</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Pick up casting, locate in fixture, lock 2 nuts, set guard, start machine.</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5+8=13</td>
</tr>
<tr>
<td>B</td>
<td>Break edges with file and clean</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5+6=11</td>
</tr>
<tr>
<td>C</td>
<td>Gauge</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5+6=11</td>
</tr>
<tr>
<td>D</td>
<td>Pick up casting, place in box, pick up new casting and place near machine.</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5+8=13</td>
</tr>
<tr>
<td>E</td>
<td>Wait for machine (unoccupied time).</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>F</td>
<td>Stop machine, open guard, unlock nuts, remove casting, place on surface plate.</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5+8=13</td>
</tr>
<tr>
<td>G</td>
<td>Clean fixture with compressed air.</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5+6=11</td>
</tr>
</tbody>
</table>

*Help labourer load and unload boxes of castings (10 per box = 68 kg / 2 men) 1/30 cycles.*
FIGURE 87. FINAL CALCULATION OF RELAXATION ALLOWANCE

The allowance which resulted from applying the percentage figures built up in figure 86 is shown opposite. It will be seen that a contingency allowance of 2½ per cent., inclusive of relaxation, was included under the heading of outside work, to cover the periods spent in discussions with the foreman and the inspector.
### Fatigue allowance

<table>
<thead>
<tr>
<th>Inside work elements</th>
<th>Basic time</th>
<th>Fatigue per cent.</th>
<th>Allowance min</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>0.25</td>
<td>6</td>
<td>0.015</td>
</tr>
<tr>
<td>C</td>
<td>0.12</td>
<td>6</td>
<td>0.007</td>
</tr>
<tr>
<td>D</td>
<td>0.19</td>
<td>8</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.037</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outside work elements</th>
<th>Basic time</th>
<th>Fatigue per cent.</th>
<th>Allowance min</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.27</td>
<td>8</td>
<td>0.022</td>
</tr>
<tr>
<td>F</td>
<td>0.26</td>
<td>8</td>
<td>0.021</td>
</tr>
<tr>
<td>G</td>
<td>0.10</td>
<td>6</td>
<td>0.006</td>
</tr>
<tr>
<td>Occasional element help labourer</td>
<td>0.04</td>
<td>30</td>
<td>0.012</td>
</tr>
</tbody>
</table>

**Contingency allowance**—
- 2½ per cent. of total basic time, inclusive of relaxation allowance:
  - Basic time: 0.03
  - Fatigue per cent.: 0
  - Allowance min: 0
  - Total: 0.70
  - Total allowance: 0.061

**Total fatigue allowance**... 0.098

### Personal needs allowance

5 per cent. of Outside work plus machine-controlled time:
- 5 per cent. of (0.70 + 0.82)... 0.076

### Total relaxation allowance

- Fatigue allowance plus personal needs allowance... 0.174
- i.e. 0.17 min
Example of a Time Study

FIGURE 88. COMPUTATION AND ISSUE OF THE STANDARD TIME

The method of computation shown opposite is that appropriate to restricted work. When compiling standard times for jobs made up wholly of manual elements it is common to add the appropriate relaxation allowances element by element, thus building up standard times for each element, the sum of which of course represents the standard time for the whole job. In such instances it is usual to show the final computations on a job summary sheet which lists the elements in full, with their descriptions, and all relevant details of the job for which the standard time has been built up. This would be done also for restricted work such as that in the present example, though inside and outside work would be shown separately. It is good practice to add a cycle diagram to the job summary sheet.

The methods adopted to issue—or publish—standard times vary according to the circumstances of the work situation. In jobbing shops, and for non-repetitive work (such as much maintenance work) jobs may be studied while they are in progress and the time standards be issued directly to the workers concerned, by annotation on the job sheet or other work instruction, after approval by the shop foreman. When the work is mainly repetitive, with the same operations being performed many times over, for perhaps weeks or months on end, tables of values, derived after extensive studywork, may be published by the work study department, on notice boards or as part of the relevant “work specifications” (see next chapter). As noted earlier, machine shop standards are frequently compiled on a “synthetic” basis (as described in Chapter 21) and for such situations it is usual to compile a “technical set-up” for each technically different group of machines. Technical set-ups are described briefly in the next chapter. In the present instance the values derived from the study on the milling operation would most probably be used in the compilation of the technical set-up for the milling section of the machine shop. From the set-up the standard times for all normal milling jobs would be derived, and these times would normally be published to the operatives concerned on the individual job cards or work tickets.

FIGURE 89. OVER-ALL CYCLE TIME

The over-all cycle time is of course the same as the standard time. The final cycle diagram is shown opposite.

*  
*   *

The use to which time standards may be put is discussed in the next chapter. It should be noted that although the example which has been studied in detail is a simple one for a manufacturing industry, very similar procedure is carried out for non-manufacturing operations or for any other work which is time-studied for the purpose of setting time standards.
### Computation of Standard Time

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside work</td>
<td>0.70 basic min</td>
</tr>
<tr>
<td>Inside work</td>
<td>0.56 basic min</td>
</tr>
<tr>
<td>Relaxation allowance</td>
<td>0.17 min</td>
</tr>
<tr>
<td>Unoccupied time allowance</td>
<td>0.26 min</td>
</tr>
<tr>
<td><strong>Standard time</strong></td>
<td><strong>1.69 standard min</strong></td>
</tr>
</tbody>
</table>

Alternatively:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside work</td>
<td>0.70 basic min</td>
</tr>
<tr>
<td>Machine-controlled time</td>
<td>0.82 min</td>
</tr>
<tr>
<td>Relaxation allowance</td>
<td>0.17 min</td>
</tr>
<tr>
<td><strong>Standard time</strong></td>
<td><strong>1.69 standard min</strong></td>
</tr>
</tbody>
</table>

**OVER-ALL CYCLE TIME: 1.69 min**

![Diagram showing time study](image-url)
1. DEFINE THE WORK COVERED BY THE TIME STANDARDS

Once the studywork has been completed it is important that a detailed record be made of the methods, tools and equipment used and of every feature of the operations which could possibly have a bearing on the time. This is necessary because changes in the work content of an operation affecting the time will also affect planning and costing; it is doubly important where the time standard is to be used in setting rates of pay under an incentive scheme. It is a cardinal principle of all sound incentive schemes based on time study that the time standards set should not be changed except when the work content of the job is changed, when there is a change in the organisation of the work, or to correct a clerical error.¹

When time standards are to be used as the basis for an incentive scheme it is usual to prepare two documents to describe and define completely the way in which time standards are compiled and the working conditions to which the standards

¹ I.L.O.: Payment by Results, op.cit., p.183.
The Use of Time Standards

refer. These two documents are known respectively as the technical set-up and the work specification.

The technical set-up is essentially a work study document, having no reference to rates of pay, control of workers or other matters of contract between employers and employees. It shows in summary form, in suitably presented tables and graphs, the main results of the studywork undertaken in the section and how all the time standards which have been set have been derived. It contains all the information necessary to compute fresh time standards, should the jobs or the working conditions change, in so far as these fresh standards can be compiled from the studywork already undertaken. It is thus in effect a manual from which time standards can be built up.

It will be necessary to compile a separate set-up for each technically different section of an enterprise, for the methods by which time standards are compiled will differ from section to section. Thus in a vitreous enamelling shop there would probably be one set-up for the sprayers, another for the operators of the shotblast machines, a third for the furnacemen, and so on.

To the technical set-up should be attached summaries of all the data on which it is based, including—

- flow process charts showing the improved methods developed;
- analysis of studies sheets;
- relaxation allowance computation sheets;
- curves and graphs relating to variable elements.

The greatest care should be taken of the technical set-up and of all the original documents attached to it, since they are essential evidence in any disputes which may arise. They are also of great value in compiling time standards for similar work in the future, and as a source of information for building up "synthetic tables" (Chapter 21, Section 4). Technical set-ups are normally filed in the work study department, where they are available to management or to the workers' representatives whenever they may be needed.

2. THE WORK SPECIFICATION

A work specification is a document setting out the details of an operation or job, how it is to be performed, the layout of the workplace, particulars of machines, tools and appliances to be used, and the duties and responsibilities of the worker. The standard time or allowed time assigned to the job is normally included.
The work specification thus represents the basic data on which the contract between employer and employee for the operation of an incentive scheme rests.

The amount of detail necessary in a work specification varies greatly according to the nature of the operation concerned. In machine shop work in the engineering industry, where a large number of different jobs are done on machines whose methods of operation are broadly similar, general conditions governing all jobs can be established for the whole shop and only variations in detail need be specifically recorded.

On the other hand, where an operation involves a whole shop or department and will run for an indefinite period substantially unchanged, as is the case in parts of the textile industry, the work specification may be lengthy and detailed. For instance, the work specification for draw-frame tenting in one spinning mill is 18 pages long and includes specifications for the alternatives of cotton or artificial fibre.

Generally speaking, the following points should be covered by a work specification, which should, of course, embrace the standard method laid down as a result of the method study:

A. Details of the workpieces or products, including—
   - drawing, specification or product number and title;
   - material specification;
   - sketch, where necessary, of parts or surfaces to be treated.

B. Details of the machine or plant on which the operation is performed, including—
   - make, size or type, plant register number;
   - speeds and feeds, pulley sizes or other equivalent data;
   - jigs, tools and fixtures;
   - other equipment;
   - sketch of workplace layout (where not available on the method study).

C. Operation number and general description of the work covered.

D. Quality standards, including—
   - quality grade;
   - finish and/or tolerances, where applicable;
   - checking and gauging requirements, gauges and other inspection apparatus;
   - frequency of inspection.

E. Grade and sex of labour, including—
   - direct and indirect labour;
   - part-time assistance by inspectors or supervisors.
The Use of Time Standards

F. Detailed description of all work involved, including—
   repetitive elements, constant and variable;
   occasional elements;
   indirect work: setting up and breaking down;
   cleaning, greasing, etc., and frequency with which carried out.

G. Details of time standards, including—
   standard time for each element, job or operation, as appropriate;
   allowed time for all indirect work, with a note on how it has
   been assessed;
   percentage relaxation allowance included in each element time;
   other allowances.

H. Clerical procedure to be carried out by operatives in recording output
   and booking waiting time.

I. Conditions under which the time standard is issued and any special
   provisos.

   It may be necessary to supply copies of the work specification to the manage-
   ment and to the departmental and shop supervision and, in the case of specifications
   affecting a large number of workers, to the workers’ representatives.

   The manner in which the time standards are made known to the operatives
   depends largely on the nature of the work. If the job is one that is only done by
   a single worker (the one who was timed) it is usually enough for the work study
   man to tell him personally, in the first instance. Once work study has been accepted
   workers do not usually want lengthy explanations; what they are interested in are
   the targets at which they must aim in order to earn a reasonable bonus. Time
   standards are likely to be better understood if they are put in the form: “You will
   need to do 12 pieces an hour for time-and-a-third”, or “17 hanks a shift for time-
   and-a-third” than in the form: “13 standard minutes per piece”. If anything
   appears to be wrong with the time standard further details will very soon be sought.
   If a whole shop is on the same type of work, as is often the case in certain process
   industries, including textile spinning, summaries of time standards should be posted
   on the notice boards in the department. It may also be desirable to read relevant
   parts of the work specification at a departmental meeting. This will have to be done
   where most of the people affected by the time standards are illiterate. In batch
   production the standard time is generally written or printed on the work ticket,
   job card or process layout.

3. THE STANDARD UNIT OF WORK

   Standard times are generally set down in the following forms:
   \[ x \text{ minutes per piece}; \]
The Use of Time Standards

\[ y \text{ minutes per hundred (or per thousand) pieces; or} \]
\[ z \text{ minutes per ton, yard, square foot, etc.} \]

They are sometimes calculated or translated into hours. These time values represent the output at standard performance, that is at 100 rating.

The minutes or hours allowed for any given job are not minutes or hours of continuous work. Each unit of time contains within it an element of relaxation.

The proportions of relaxation and work will vary according to the heaviness of the work. In extremely heavy, hot work such as furnace tending the proportion of relaxation may be 50 per cent. or more.

Since the standard minute is a measure of output it can be used in measuring and comparing productivity, which may be represented by the ratio—

\[
\text{Performance} = \frac{\text{output of work in standard minutes}}{\text{input of labour time or machine time in clock minutes}} \times 100
\]

A particular advantage of the standard minute is that it can be used to measure and compare outputs in dissimilar types of work, the accuracy of the comparison being limited by the consistency of the time standards.

4. PRODUCTION PLANNING AND THE UTILISATION OF PLANT AND LABOUR

One of the causes of ineffective time due to management shortcomings mentioned earlier is "failing to plan the flow of work and of orders, with the result that one order does not immediately follow on another and plant and labour are not continuously employed".

In order to plan a programme of work effectively, it is necessary to know precisely—

1. What is to be made or done.
2. The quantity involved.
3. What operations are necessary to carry out the work.
4. What plant, equipment and tools are needed.
5. What types of labour are needed.
6. How long each operation may be expected to take.

1 See pp. 29–32.
7. How much plant and equipment of the types necessary are available.

8. How much labour of the types necessary is available.

The information on items 1 and 2 is generally supplied by the sales office or commercial department.

The information for determining items 3, 4 and 5 is supplied by process planning and method study.

The information on item 6 is supplied by work measurement.

The information on item 7 is supplied from plant department records or those of the department concerned.

The information on item 8 is supplied from personnel office records or those of the department concerned.

Once this information is available it becomes a matter of simple arithmetic to match the requirements with the available capacity. Both the requirements and the capacity available to fulfil them must be stated in terms of time.

Requirements will be stated as—
number of operations of each type to be performed \( \times \) expected time for each operation.

This must be matched against the total time available on each type of plant and with each type of labour necessary to perform the operations.

In planning a programme only the actual times which the operations may be expected to take are of interest. These will depend, among other things, on whether the general conditions in the plant—including the state of labour-management relations and the system of remuneration in use—are such that the workers are working at their best rate. Where this is the case and the work study application has had time to settle down, these times should be those of the average performance of the shop or department as given by the production records over a period. This may even apply to an individual machine or process. It is the only realistic basis for such calculations. The times are arrived at by multiplying the standard times by

\[
\frac{100}{\text{Average performance}}
\]

The plant and labour capacity available is expressed in “man-minutes” or “machine-minutes”, due regard being paid to any time which it is necessary to allot for cleaning, setting up, dismantling, change-overs, repairs, etc.
The Use of Time Standards

The matching up of production or operational requirements against capacity in this way makes it possible to—

- show whether there is an insufficiency of any type of plant or labour likely to hold up the programme or cause bottlenecks in the course of production and, if so, its extent;
- show whether there is an excess of capacity in any type of plant or labour and its extent;
- give accurate estimates of delivery dates.

If management can have such information, compiled from realistic standards of performance, available well before production is due to start, it can take steps to prevent hold-ups from occurring. Alternatively it can start looking for work to fill up spare capacity. Without such standards it has no sure basis for doing either of those things.

5. ESTIMATING PRODUCTION COSTS

The success or failure of a firm in a competitive market may depend on the accuracy with which it is able to price its products. Unless the manufacturing time of the product is accurately known the labour cost cannot be estimated, and many indirect costs dependent on time, such as plant depreciation, fuel and power consumption, rent, and the salaries of staff and supervision cannot be accurately determined.

If the management can rely on the accuracy of the costing, economic prices can be fixed. If these are below those of the firm's competitors, the management can be happy in the knowledge that it is underselling them in safety; if they are above, the cutting of costs can be undertaken with more assurance than would otherwise be the case and with a knowledge of the margins available to be cut.

Standard and actual labour costs per 100 or per 1,000 standard minutes of production are frequently calculated each week from the weekly control statements. Since the actual labour cost per 100 standard minutes takes into account both direct and indirect labour costs it is the more useful figure to use for estimating production costs.

6. STANDARD COSTING* AND BUDGETARY CONTROL

Work measurement provides the basic information for setting standards of labour costs and the means of controlling them. These standards can also be used as the basis of the labour budgets for budgetary control*; they provide certain elements of the information necessary for the production and indirect expense budgets and, related to the sales budget, indicate the plant and labour capacity likely to be available over the period of the budget.
Besides providing the standards, work measurement also provides, accurately, the actual performance figures. The need for such accurate standards cannot be overstressed. The absence of complete cost information is at the root of much bad management and of many failures of industrial enterprises. Labour costs will, as usual, be based on standard times, with appropriate provisions being made for deviations from standard performance.

7. INCENTIVE SCHEMES

Direct incentive schemes based on output do not necessarily follow on an application of work measurement. There are many enterprises where time studies are made but direct incentives are not employed. One of the reasons why a good deal of attention has been paid in the last two chapters to features of time study particularly related to its use in connection with incentives is that no discussion of time study would be complete without them; moreover, in practice the installation of an incentive scheme is generally one of the principal objects of a time study application.

This is not the place to discuss the pros and cons of direct incentive schemes, or to describe the various types of scheme suitable for different circumstances. The reader is referred to an I.L.O. study on this subject.1

The merits of work measurement as a basis for incentive schemes lie in several features inherent in the techniques, namely—

(a) That the times are based on direct observation and on recording by the most accurate practicable means.

(b) Sufficient observations are taken of all elements of work, both repetitive and occasional, to ensure that the times finally selected to make up the standard time are truly representative and that random occurrences are taken into account.

(c) Full records are made and retained so as to be available for examination by either management or workers should the occasion arise.

(d) The recorded times and associated data give a factual basis to any management-labour negotiations on performance standards, as opposed to the bargaining based on opinion which must take place when times are estimated.

(e) Properly applied method study followed by work measurement enables management to guarantee the time standards with reasonable assurance that it is not exposing itself to risks of perpetuating uneconomic rates.

---

1 I.L.O.: Payment by Results, op. cit., and in particular Chapter VIII, which contains the conclusions of an I.L.O. meeting of experts on this subject.
It is important for the success of any incentive scheme that the workers should know as quickly as possible the bonus they have earned. Wherever possible this information should be made available the day after the one to which it refers. It may be shown in money units, as a percentage of the standard performance, or as the average number of standard minutes produced per hour. In these latter ways the figures can be posted on the notice board without workers actually seeing each other’s earnings. In many firms it is the practice for the shop clerk or foreman to tell each operator his performance, which enables him to raise any queries on the spot. Once workers get used to thinking in standard minutes, they generally know at the end of each day what they have earned and tend to regard the daily figures as confirmation.

The value of this practice to an incentive scheme is as follows:

(a) The effect of the operator’s own actions on his earnings is brought home to him while the events concerned are still fresh in his mind.

(b) Any queries on the amount of bonus due can be taken up and corrections made, if necessary, before the wages are made up.

(c) The posting of the figures daily on the notice board, where this has been agreed to by the workers and their representatives, adds an interest and may stimulate a competitive spirit.

(d) Repeated confirmation of their own calculations by the management’s figures or clear explanations where they differ, tend to increase the confidence of the workers in the fairness of the system. Conversely, repeated mistakes by the wages staff can rapidly undermine confidence.

8. ORGANISATION OF THE RECORDING SYSTEM ASSOCIATED WITH WORK MEASUREMENT AND LABOUR CONTROL

A full application of work measurement, when associated with an incentive scheme, has to be backed by a system of recording operatives’ times and output of work. These times and output figures must then be assembled at a central point—usually the accounts department once the work study application is running properly—where they can be worked out and put into forms suitable for use in compiling the bonus earned by each worker and providing the management with compact and easily understandable statistics for the control of factory performance and costs. Devising a system suitable for use in the organisation in which he is employed is generally one of the jobs of the work study man. Any such system must have certain characteristics. It should—

(a) provide accurate and full information;

(b) ensure that all the necessary information is recorded as a matter of routine and transmitted with the minimum delay to the central office;
(c) be simple to understand and to operate and as nearly as possible fool-proof, so that all the routine work can be carried on by comparatively unskilled clerical staff;

(d) be economical of staff;

(e) be economical of paper.

Working out a system to fulfil all these requirements for any but the smallest works engaged on the simplest type of manufacturing is not easy, and a chapter could well be devoted to the subject. Space does not, however, permit this, and the variety of systems for different applications is such that any set of examples given here would run the risk of being too complicated for some enterprises and insufficient for others. Comment will therefore be confined to some general notes and to the basic data required together with its probable source.

The sheets on which output and performance information is summarised and reported to management are known as control statements. In a fully developed labour control system there will probably be three different labour control statements, prepared at different intervals and for different purposes. A daily statement may be prepared each morning, separately for each section of the organisation, to indicate to the foreman or supervisor in charge of the section the results of the previous day’s working. Once a week the weekly control statement\(^1\) will be compiled, usually on a departmental rather than a section-by-section basis. The weekly statement will go to both foremen and departmental heads. A single sheet frequently has space for the record of 13 weeks’ work, a fresh line being used each week, so that the current week’s results can be compared with those of earlier weeks during the same quarter. The control statement which goes to top management is usually made up monthly, either on a departmental or whole-works basis.

In any system of recording associated with work measurement and an incentive system, the minimum data given in the table opposite must be recorded and eventually transmitted to the wages and cost offices.

It should be noted that the application of work measurement will almost certainly entail an increase in clerical staff. The idea of this frightens many managers who fear increases in their overhead expenses, forgetting that the increased cost is likely to be very small compared with the savings which the techniques of work study can make in their total costs of production or operation.

The design of labour control statements varies according to the needs of the organisation, but the usual form is divided into two parts. In the first part the labour utilisation and effectiveness are expressed in terms of time and in the second the figures are translated into costs. In addition to the output (in standard minutes) and the clock minutes worked, from which the productivity of the department may

\(^1\) For an example of a weekly analysis sheet see I.L.O.: *Payment by Results*, op. cit., pp. 47-48.
be calculated, waiting time and additional allowances are analysed by causes so that the manager can at once question and take action on any cause of excessively high waiting time, and can see the cost of it.

<table>
<thead>
<tr>
<th>Information</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Hours of attendance of each operative</td>
<td>Clock card or time sheet</td>
</tr>
<tr>
<td>(2) Standard time for each operation</td>
<td>Job card or work study office</td>
</tr>
<tr>
<td>(3) Times of starting and finishing each operation</td>
<td>Job card or work sheet (via shop clerk)</td>
</tr>
<tr>
<td>(4) Quantities produced</td>
<td>Job card or work sheet (via work checker)</td>
</tr>
<tr>
<td>(5) Scrap or rectification: quantities and times</td>
<td>Scrap note or rectification slip (via inspector and shop clerk)</td>
</tr>
<tr>
<td>(6) Waiting time and non-productive time</td>
<td>Waiting time slips or daily work sheet (via shop clerk)</td>
</tr>
</tbody>
</table>

* * *

This concludes the section of the book devoted to time study. In the next chapter some of the other techniques of work measurement will be discussed.
OTHER TECHNIQUES
OF WORK MEASUREMENT

In work study, as in other activities, it is as well to learn to walk properly before trying to run. With the exception of production study, which is merely a special use of time study and which is necessary from the beginning, the trainee should not bother about the techniques discussed in this chapter until he has obtained a real understanding and considerable experience of time study. They should then be attempted only under the guidance of experts. It is felt, however, that readers should be aware of their existence. That is the reason for their inclusion.

1. THE PRODUCTION STUDY

A production study is a continuous study of relatively lengthy duration, often extending over a period of one or more shifts, taken with the object of checking an existing or proposed standard time, or obtaining other information affecting the rate of output.
Other Techniques

The purpose of production studies is to make sure that nothing that occurs during the working period is overlooked. They are especially concerned with interruptions, work of an occasional nature and ineffective time due to any cause which is not likely to appear, or to appear with any frequency, in ordinary time studies.

Specific uses of production studies are—

(a) In initial applications, to ensure that the time standards do in fact cover all the activities involved.

(b) To check the accuracy of time standards.

(c) To observe the incidence of waiting time and other delays to which the operative may be subject.

(d) To obtain data on which to compile interference and contingency allowances.

(e) To record the performance of a section or a department for future reference.

(f) Where a time is challenged or a complaint made by workers or their representatives, to find out whether any elements have been inserted in the operation that were not allowed for in the original time, or any other factors which would make the time tight.

(g) As a check when the output of an operative is showing a downward trend.

(h) As a check on the amount of relaxation actually taken by the workers, to compare this with the aggregate amount of the relaxation allowance embodied in the standard times.

It is a common practice to make a series of production studies in a department before starting detailed time studies in order to obtain information on the general state of the department, to uncover and eliminate delays and generally to get jobs running smoothly before attempting to set time standards. Making such studies is tedious since it involves hours of continuous standing and walking. The observer starts recording at the beginning of the working period and continues recording productive time and all delays and other ineffective time until the end of it. Several shifts or days may have to be studied to obtain a complete picture.

The stopwatch is allowed to run continuously and, in addition, the time is recorded every half-hour from an ordinary watch. Regular repetitive elements are not usually recorded. If, however, the study is being made to check an existing time standard, care must be taken to make it in such a way that the elemental
FIGURE 90. EXAMPLE OF PART OF A PRODUCTION STUDY

<table>
<thead>
<tr>
<th>STUDY No. 18</th>
<th>TIME STUDY CONTINUATION SHEET</th>
<th>SHEET No. 1 OF 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start 8.00 a.m.</td>
<td>75</td>
<td>000</td>
</tr>
<tr>
<td>Clean machine</td>
<td>75</td>
<td>050</td>
</tr>
<tr>
<td>table, switch on</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>power, take gauge</td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td>from tool locker and</td>
<td>75</td>
<td>200</td>
</tr>
<tr>
<td>prepare workplace</td>
<td>75</td>
<td>250</td>
</tr>
<tr>
<td>Load machine and start</td>
<td>75</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>325</td>
</tr>
<tr>
<td>Load machine and start</td>
<td>75</td>
<td>362</td>
</tr>
<tr>
<td>A (Machine time)</td>
<td>444</td>
<td>82</td>
</tr>
<tr>
<td>H (Unload, clean machine, reload, start auto cycle, clean, gauge and put aside finished casting, place new casting on table)</td>
<td>80</td>
<td>579</td>
</tr>
<tr>
<td>A</td>
<td>597</td>
<td>18</td>
</tr>
<tr>
<td>H</td>
<td>90</td>
<td>725</td>
</tr>
<tr>
<td>A</td>
<td>750</td>
<td>25</td>
</tr>
<tr>
<td>H</td>
<td>85</td>
<td>880</td>
</tr>
<tr>
<td>A</td>
<td>90</td>
<td>20</td>
</tr>
<tr>
<td>H</td>
<td>80</td>
<td>1033</td>
</tr>
<tr>
<td>A</td>
<td>1051</td>
<td>18</td>
</tr>
<tr>
<td>H</td>
<td>95</td>
<td>1174</td>
</tr>
<tr>
<td>A</td>
<td>1198</td>
<td>24</td>
</tr>
<tr>
<td>H</td>
<td>90</td>
<td>1325</td>
</tr>
<tr>
<td>A</td>
<td>1346</td>
<td>21</td>
</tr>
<tr>
<td>H</td>
<td>95</td>
<td>1623</td>
</tr>
<tr>
<td>A</td>
<td>1647</td>
<td>24</td>
</tr>
<tr>
<td>H</td>
<td>100</td>
<td>1767</td>
</tr>
<tr>
<td>A</td>
<td>1793</td>
<td>26</td>
</tr>
<tr>
<td>H</td>
<td>85</td>
<td>1925</td>
</tr>
<tr>
<td>A</td>
<td>1942</td>
<td>17</td>
</tr>
<tr>
<td>H</td>
<td>85</td>
<td>2072</td>
</tr>
<tr>
<td>A</td>
<td>2089</td>
<td>19</td>
</tr>
<tr>
<td>H</td>
<td>95</td>
<td>2212</td>
</tr>
<tr>
<td>A</td>
<td>2235</td>
<td>23</td>
</tr>
<tr>
<td>A</td>
<td>2363</td>
<td>128</td>
</tr>
<tr>
<td>H</td>
<td>100</td>
<td>2504</td>
</tr>
<tr>
<td>A</td>
<td>2527</td>
<td>23</td>
</tr>
<tr>
<td>H</td>
<td>90</td>
<td>2654</td>
</tr>
<tr>
<td>A</td>
<td>2290</td>
<td>21</td>
</tr>
<tr>
<td>H</td>
<td>90</td>
<td>2417</td>
</tr>
<tr>
<td>etc., etc.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Other Techniques

time values can be checked with the original study. It is permissible to rate the operative every half-minute.

Symbols may be used for the different activities. Figure 90 is an example of one sheet of a production study made to check the contingency allowance and handling time in the milling operation used in the time study example. The standard general-purpose time study forms can be used.

In figure 90 the following symbols have been used:

\[ H = \text{All handling time connected with loading, unloading, de-burring, cleaning, etc., in operating the machine.} \]

\[ A = \text{Time when the machine is running automatically and the worker is not working.} \]

Watch readings and subtracted times are in minutes and decimals of a minute as in the example of a time study (figures 80, 81 and 82); for example, watch reading 2072 means 20.72 mm; subtracted time 130 means 1.30 mm.

In this example it will be seen that apart from the help given to the labourer in loading and unloading boxes of castings there were interruptions due to the foreman and to a progress man checking the batch number. All these interruptions were devoted to discussing the work, and on the basis of a prolonged study it was decided to allow 2½ per cent. contingency allowance. Talking to a fellow-worker was not, however, an unavoidable delay in this case.

It will be noted that hand work in this study has been rated so that the study can be used not only to study interruptions and delays with a view to determining allowances but also, if necessary, as a check on the validity of the standard time. The activities at the beginning, which extend over 3.25 min, have been rated every 30 seconds (0.50 min), but subsequently the hand time has been rated as a whole. The times are of fairly short duration and, over the very large number of cycles which will be studied, rating in this way will give sufficiently accurate results.

Once the complete study has been made it must be summarised to show the total time spent on productive work, on contingencies, and in taking relaxation. The subtracted times are extended to basic times and an average rating for the study is worked out. The amount of production during the period of the study is also recorded, and the proposed standard times are applied to this quantity of output to derive the over-all performance of the operative over the period. This may then be compared with the average rating observed. The actual amount of relaxation taken is compared with the aggregate amount allowed in the proposed standard times, and, similarly, the actual contingencies experienced are compared with the contingencies allowance made. If there are significant differences the investigation must be continued until the explanations for them are discovered.
2. ACTIVITY SAMPLING

Activity sampling is a technique in which a large number of instantaneous observations are made over a period of time of a group of machines, processes or workers. Each observation records what is happening at that instant and the percentage of observations recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs.

There have been very few original developments in time study since F. W. Taylor laid down its original lines. Taylor used what are now known as “production studies” for recording delays and interruptions, essentially in the form described in the previous section. The drawback of production studies is the time they take to carry out. Work study departments are generally very busy, and it is difficult to spare work study men for the days and even weeks necessary to perform production studies throughout a whole department, since only one machine, operator or working group can be studied at one time. Where one work study man only is employed production studies are almost impossible.

Activity sampling provides a solution. It is a statistical technique originally developed under the title of “snap reading technique” by L. H. C. Tippett in 1934. It is extensively used in the textile industry, for which it was developed, and also in other industries where large numbers of similar machines and workers engaged on similar tasks are employed. It can also be used in the determination of work loads in large offices.

Activity sampling, as its name implies, is a sampling technique. If it were possible to look down on a whole shop full of machines continuously, day in and day out, and record every stoppage of every machine, a complete picture of the production time and stopped time for the whole shop for that period would have been obtained. This would be impossible without keeping a large number of men permanently on the job.

If it were possible to note at one glance the state of every machine in the shop at a given moment one might see 80 per cent. of the machines working and 20 per cent. stopped. If this action were repeated 20 times at different times of the day and there were always 80 per cent. of the machines working, it might become

---

1 Activity sampling is also known as: ratio-delay study; observation ratio study; snap-reading method; random observation method; and work sampling.

possible to say with some assurance that at any time there were always 80 per cent. of the machines working.

It is not generally possible to do this, so the next best method must be adopted, that of making a series of tours of the shop at irregular intervals, noting the machines working, the machines stopped and the cause of each stoppage. If a sufficiently large number of readings are taken at random intervals the percentage of readings recording a machine working will tend to equal the percentage time it is doing so. The percentage of readings recording an operative as doing a certain operation or group of operations is an estimate of the percentage of time actually spent on these operations. If the readings are distributed at random over a long enough time this relationship holds good whether the stoppages are short or long, many or few, regular or irregular.

The type of information provided by an activity sampling study is—

(a) The proportion of the working day during which workers or machines are producing.

(b) The proportion of the working day used up by delays.

The reason for each delay must be recorded.

(c) The relative activity of different workers and machines.

In order to make an activity sampling study the observer requires a number of duplicated sheets representing a stylised plan of the shop with a space for each machine or a sheet for each group of machines of the same type or making the same product. He sets out on a systematic tour of the shop, machine by machine or workplace by workplace. If the machine is running he makes a mark or a tick and passes on to the next; if it is stopped he must find out the reason, if this is not obvious. He then marks against that machine a code letter to denote the cause of the stoppage.

Two things are specially important. The first is that, although the observer may follow the same path every time, each tour should be made at a different time of the day. This avoids always noting a stoppage which occurs regularly at the same time, such as a tea break. The second is that each observation should be made at the same point relative to each machine, such as at the moment the observer comes abreast of it. He should not note what is happening at machines ahead of him as this tends to falsify the study. For example, while studying in a weaving shed the work study man may notice a loom with an end down just ahead of the one he is noting. The weaver may have it running again by the time he reaches it. If he were to note it as down he would be giving an untrue picture.

Operatives must be persuaded to carry on as if the observer were not there. If they are resting they should continue to do so. Members of the I.L.O. mission in Pakistan found that their first readings in weaving sheds were apt to be falsified
by the jobbers (overlookers) and assistant weaving masters going ahead of them and helping the operatives to get their looms running quickly.

Figure 91 gives an example of a sheet used for an activity sampling study in a weaving shed with a list of the symbols used for the different types of stoppage. This particular form is drawn to correspond with the actual layout of the machines in the building, which contained 252 looms. Another style of record sheet, also for a weaving shed, is shown in figure 92. This one can be used to accommodate up to 25 tours of the shop, and there is space vertically for observations on 25 operatives or machines. By using continuation sheets any number of machines can be recorded. It is usual for each work study office to design its own record sheets, as convenient for the type of observations to be made, and to establish a code of symbols appropriate to the work being studied. If the only observations required are simply whether a machine is running or stopped, a very simple record of the type illustrated in figure 93 will suffice.

Number of Observations Required

In all sampling there is bound to be some error between the data obtained from the sample and the facts. The larger the sample the nearer the data will be to presenting a true picture of the facts. The error which is inherent in the observed percentages, or conversely, the number of observations required to obtain a required degree of accuracy, are calculable from a simple formula. The derivation of the formula may be found in textbooks on statistics.

A relationship between number of observations (N), the extent of the phenomenon being observed, expressed as a decimal (p), and the accuracy of the sample results (S) which satisfies the formula

\[ S_p = \frac{2 \sqrt{p(1-p)}}{N} \]

may be accepted as having a 95 per cent. chance of truly representing the actual situation.¹

It is easiest to see how the formula is used by considering an example. Let us suppose that activity sampling is to be used to determine what proportion of a batch of ten machines can be taken as stopped, on average. A preliminary study is first made, totalling 100 observations—the observer has made ten tours of the shop at different times of the day, and has noted on each tour which machines are working and which are stopped. It was found that the total of 100 observations was made up of 70 observations of machines working and 30 of machines stopped.

¹ For 68 per cent. probability the corresponding formula is: \[ S_p = \sqrt{\frac{p(1-p)}{N}} \]

For 99 per cent. probability: \[ S_p = \frac{3 \sqrt{p(1-p)}}{N} \]
**Figure 91. Example of an Activity Sampling Record (Weaving Survey)**

<table>
<thead>
<tr>
<th></th>
<th>20's counts cloth</th>
<th>40's counts cloth</th>
</tr>
</thead>
<tbody>
<tr>
<td>WALL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>WALL</td>
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<tr>
<td>WALL</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DATE:** 11. 6. 55

**TIME STARTED:** 10.30 a.m.

**TIME FINISHED:** 11.15 a.m.

**TEMP. DRY-BULB:** 92° F.
**WET-BULB:** 83° F.

**RH:** 70% (relative humidity)

**CODE**
- **x** = Loom running
- **T** = Warp break
- **To** = Warp break—operator attending
- **W** = Warp out
- **O** = Warp out
- **R** = Warp break
- **G** = Smash
- **Ko** = Bang-off
- **Sm** = Smash
- **B** = Bang-off
- **B** = Bang-off
- **G** = Warp gaiting
- **R** = Under repair

<table>
<thead>
<tr>
<th></th>
<th>20's counts cloth</th>
<th>40's counts cloth</th>
</tr>
</thead>
<tbody>
<tr>
<td>WALL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>WALL</td>
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<tr>
<td>WALL</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

**N.B.** Each square represents one loom.
## FIGURE 92. ANOTHER STYLE OF FORM FOR AN ACTIVITY SAMPLING STUDY IN A WEAVING SHED

<table>
<thead>
<tr>
<th>Date:</th>
<th>Observer:</th>
<th>Study No.:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Machine or operative</th>
<th>Tour No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
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<td>5</td>
<td></td>
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<td>6</td>
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<td>11</td>
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<td>23</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

**Code:**
- Machine running: √
- Warp break: T
- Operative working: W
- Change-over: X
- 'Empty' battery: B
- Operative resting: RA
- Cleaning: C
- Weft break: W
- Operative absent: PA
- Maintenance: M
- Smash: Sm
Other Techniques

FIGURE 93. SIMPLE RECORD SHEET

<table>
<thead>
<tr>
<th>Date:</th>
<th>Observer:</th>
<th>Study No.:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of observations:</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Machine running</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Machine stopped</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The percentage of the phenomenon we are interested in—machines stopped—thus appears to be 30 per cent., or, expressed as a decimal, 0.30. The value of $p$ for the formula is therefore 0.30.

If we are prepared to accept an accuracy of ± 5 per cent. in the result we finally obtain for the proportion of machines stopped (i.e. $S = 0.05$) we can now use the formula to calculate the number of observations required before we can feel 95 per cent. sure that the sample results represent the true situation. For this purpose it is convenient to rearrange the formula into the form:

$$N = \frac{4(1-p)}{S^2p}$$

Entering $p = 0.30$ and $S = 0.05$ yields a value for $N$ of 3,733 observations, which we may round off to 4,000.

As there are ten machines this indicates a total of 400 tours, which could be accomplished by a single studyman making 40 tours a day, at intervals of approximately 12 minutes, for ten working days.

At the end of the first day approximately 400 observations will have been completed. Let us suppose that 100 of these were of machines that were stopped, so that the value of $p$ should now be set at 0.25 instead of 0.30. Applying the formula again indicates that $N$ is now 4,800, to give the required degree of accuracy.

At the end of 12 days, when 4,800 observations had been taken, it was found that 1,344 of these were on machines which were stopped, so that the final value of $p$ was

$$\frac{1,344}{4,800} = 28 \text{ per cent. or } 0.28$$

Introducing this figure into the formula, and also the final value for $N$ (4,800), permits solving for $S$, the accuracy of the observation. When this is done, $S$ comes
out at 0.046, or 4.6 per cent. This is less than the ± 5 per cent. originally sought, so enough observations have been taken.

It may thus be said that there is a 95 per cent. chance that the actual proportion of machines stopped will average 28 per cent. ± 4.6 per cent. We may therefore be 95 per cent. confident that the machines are stopped between 32.6 and 23.4 per cent. of their time.

The combination used in the example above, a 95 per cent. probability and accuracy to plus or minus 5 per cent., is a fairly common one when applying activity sampling in industrial situations. If an accuracy of ± 10 per cent. had been considered acceptable, only 933 observations would have been necessary, with the same 95 per cent. probability. An accuracy of ± 15 per cent. would need only a few more than 400 observations. Accuracies of this order are sometimes acceptable in industrial applications of activity sampling, particularly when the purpose is to obtain a quick over-all view of the situation.

Readers requiring combinations other than those illustrated above should consult texts on statistical analysis methods and apply the relevant formulae in analogous fashion.

Using Activity Sampling

It is important that the days chosen to make tours of observation should be representative of normal working and thus not biased by special occurrences, holidays, etc. In the ordinary way the tours should be carried out at random intervals, and many study offices use tables of random numbers (printed in statistical texts) to ensure this. However, when the stoppages themselves occur at random intervals, as is usually the situation in textile mills, experience suggests that adequate accuracy can be obtained by making tours at regular intervals of time.

One of the advantages of the technique is that observers do not need long periods of training before they can produce usable results. The observer does need to be familiar with the process, however, so that he can recognise at a glance the reason for a particular stoppage.

It will readily be appreciated that the technique of activity sampling is not confined in its application to the determination of the proportion of machines in a given workshop which are stopped. It can be applied to observing the activities of groups of workers and teamwork, and is often so used when the information which is required does not justify the expense and delay which would be entailed in using full-scale time study methods. It is commonly used when studying the utilisation of trucks, cranes, trolleys and other internal transport equipment.

Morrow¹ quotes the conclusions of three engineers who carried out activity sampling studies in factories in the United States. They are worth quoting in full.

Other Techniques

(1) Only homogeneous groups should be combined, such as delays on similar types of operations performed on similar types of machines or delays of operators on work of a similar nature.

(2) A large number of observations is recommended, and studies are best adapted to large groups of machines or operators. When the number of observations on the job was 500 a fairly reliable result was obtained. Over 3,000 observations gave very accurate results.

(3) Results from a few hundred observations may be used if the frequency distribution conforms to the binomial law.

(4) The accuracy of the results may be determined in any case.

(5) As the percentage of delay time increases, more observations are necessary for a given accuracy.

(6) Data are more reliable if the observations are taken over a long period of time.

(7) Observations must be taken at random intervals and distributed over all hours of the day and week.

(8) Intervals between samples must be large enough to give independent readings.

(9) The [activity sampling] study provides an opportunity to observe and evaluate operations of the department as a whole.

(10) The observers' work may be interrupted at any time without affecting the study. Taking studies is not tedious for the observer.

(11) There has been no objection to [activity sampling] studies by operators because no stop-watch was used.

(12) The cost of studies is about one-third that of production studies.

3. RATED ACTIVITY SAMPLING

Rated activity sampling is an extension of activity sampling in which a rating is applied to each work element so that the work content may be established in addition to the proportion of time occupied by other activities or delays.

Rated activity sampling is often of value when the work of teams of operatives has to be studied, especially when the results are not required to have quite the same precision as is obtainable by using time study. The procedure is much the same as that adopted when straightforward activity sampling is used, except that each time an operative is observed the activity he is engaged on is noted, and the
speed and effectiveness with which he is carrying out the activity is rated. It is
necessary to draw up special forms to allow this to be done, each form being
appropriate to the work situation being studied.

When there is a clear distinction between working time and idle time, rated
activity sampling can be used to produce time standards for repetitive manual
tasks which are substantially the same as standards obtained by time study. For
activities in which a production count is not easy to obtain, such as indirect labour
operations, it is possible to obtain a performance index for the operator studied,
during the period studied, and such measurements can be made with a known
degree of reliability, provided that sufficient observations are recorded.

The technique does call for a good deal of experience, however, and should
not be attempted without expert guidance, except perhaps as an initial rough
survey of a shop or department when it is intended to give an approximate indica-
tion of the idle time and delays being experienced, and of the general level of
performance at which the operatives are working.

4. SYNTHESIS

Synthesis is a work measurement technique for building
up the time for a job at a defined level of performance by
totalling element times obtained previously from time
studies on other jobs containing the elements concerned,
or from synthetic data.

Synthetic data is the name given to tables and formulae
derived from the analysis of accumulated work measure-
ment data, arranged in a form suitable for building
up standard times, machine process times, etc., by
synthesis.

Synthetic times are increasingly being used as a substitute for individual time
studies in the case of jobs made up of elements which have recurred a sufficient
number of times in jobs previously studied to make it possible to compile accurate
representative times for them.

The advantages of synthetic times over times compiled by individual studies
are—
Other Techniques

(1) They are usually based on data derived from a large number of studies and are thus more reliable than times derived from a single study.

(2) Where the elements for which synthetic times have been compiled recur repeatedly in various jobs performed in the undertaking, so that the work involved in compiling such times is justified, they often eliminate the need for prolonged individual studies, although it is usual to make a short check study after the synthetic time has been compiled in order to ensure that no activity has been overlooked.

(3) They are valuable in estimating time standards for production planning and estimating for quotation purposes.

(4) They are useful in planning teamwork activities such as an assembly line or group working, as in garment making, to reduce unbalance in the early stages.

When compiling synthetic times it is most important that the operations providing the basic data should have been timed under identical conditions; in particular, similar methods and equipment must have been used and the operation must have been broken down into identical elements. The possibility of using data from any one study as a basic for synthetic times is one of the reasons for making a precise and full work specification at the time of issue of the time standards.

Three types of element may be encountered when compiling synthetic times—

(1) Elements which are identical from job to job (constant elements).

(2) Elements which are similar in nature but vary in difficulty and in the length of time necessary to perform them as the size, weight, pressure, etc., involved (variable elements).

(3) Elements which are controlled by the physical or technical characteristics of the material and the process, including automatic machine elements controlled by feed, speed, depth of cut, etc.

Elements in the first group are easy to deal with; it is merely necessary to amass sufficient studies on them to ensure that a really representative time is obtained.

Elements in the second group will have to be given a series of time values varying with the variable characteristic of the element. Sufficient studies will have to be taken to ascertain the law governing the relationship between the characteristic and the time of performance of the element, that is, whether it is a straight-line relationship or in the form of a curve. The treatment of variable elements was discussed in Chapter 17, Section 4.
Elements in the third group can generally be calculated from physical data (length, diameter, speed of rotation, rate of feed, etc.).

The handling elements of operations on machine tools are singularly well adapted to be the subjects for synthetic times, since for any given machine tool they are generally fairly limited in number, and many of them are repeated every time an operation is performed on the machine, irrespective of the nature of the workpiece. Synthetic times can be compiled for machines and plant in many other industries such as the cotton industry, woodworking, pottery, glassmaking, and for many types of manual operations where a comparatively limited range of elements tend to recur in different combinations from operation to operation.

Most organisations which have had a work study department for a few years have built up synthetic tables covering the commoner elements in their own type of work. Two countries at least (France and the Federal Republic of Germany) have central organisations which have compiled tables of synthetic times for many operations. The Bureau des temps élémentaires in France has synthetic handling and cutting times for a large number of French and foreign machine tools and for many hand operations such as welding, building operations, woodworking and many of the operations involved in the manufacture of airframes.

5. ANALYTICAL ESTIMATING

Analytical estimating is a work measurement technique whereby the time required to carry out elements of a job at a defined level of performance is estimated from knowledge and practical experience of the elements concerned.

The setting of reasonably accurate time standards for non-repetitive work has always been a problem in industry. It is often quite uneconomic to use time study to do so. On the other hand, the old-fashioned type of rate-fixing was often merely a process of bargaining in which neither side had any sound basic information to work from and each was only able to counter opinion with opinion.

Analytical estimating represents a compromise between straight rate-fixing and time study. The essential features of analytical estimating are—

(a) The employment of craftsmen skilled and experienced in the work concerned as estimators.

1 The information on analytical estimating has been supplied by Imperial Chemical Industries Ltd. For a fuller explanation of the technique the reader is referred to R. M. Currie: The Measurement of Work (London, British Institute of Management, 1965).
Other Techniques

(b) Giving these craftsmen a thorough training in work study, including both method study and time study. It is important that they should be able to recognise standard-performance rates of working.

(c) The making of an initial method study of the job in as much detail as is economic.

(d) Breaking the job down into elements and determining a time for each element based on standard performance. Where possible, element times are derived from time study data or synthetic times. Where no such data exist, times are estimated on the basis of the estimator’s experience.

(e) When all the element times at 100 rating have been determined they are added together and the total basic time for the operation is worked out. Relaxation allowances are added as a percentage of the total time. Any additional allowances are then added.

Analytical estimating has been extensively used in the field of plant maintenance and repair work, where it is of special value in the planning of programmes of preventive maintenance. It can also be used in jobbing shops for estimating production times. The results can be used for the same purposes as those derived from the other techniques of work measurement, provided that the limits of their accuracy are recognised.

While the theory of analytical estimating is simple, there are practical problems in its application which make it unsafe for use by inexperienced work study men. The guidance of an expert should be sought before attempting to introduce a scheme.

6. PREDETERMINED MOTION TIME SYSTEMS (P.M.T.S.)

A predetermined motion time system is a work measurement technique whereby times established for basic human motions (classified according to the nature of the motion and the conditions under which it is made) are used to build up the time for a job at a defined level of performance.

From the synthesising of operation times by combining predetermined element times compiled within the organisation to the synthesising of operation times from predetermined times of basic human movements assumed to be universally applicable is not a very great step in theory, but the practical problems of finding elements
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which would have the widest possible application and of obtaining really representative times retarded the appearance of workable systems.

Gilbreth had conceived the idea of universal elementary motions which he called therbligs (see Chapter 11, Section 9) and Segur⁰ developed a predetermined motion time system based on Gilbreth's therbligs which he called Motion Time Analysis. Since 1930 a good deal of work has been done in this field, particularly in the United States, and this has resulted in the appearance of a number of practical systems, three of which are work factor, methods-time measurement (M.T.M.), and basic motion time study.

These systems are based on the assumption that all manual tasks can be analysed into basic motions of the body or body members. They were compiled as a result of a very large number of studies of each movement, generally by a frame-by-frame analysis of films of a wide range of subjects, men and women, performing a wide variety of tasks.

When using these systems to compute the standard time for a job, the operation is first analysed into its component motions, going into much greater detail than is normally done in method study analysis, even when two-handed charts are being compiled. The way in which each motion has to be carried out is visualised, the distance involved is estimated, and the motion is classified according to such factors as the difficulty which making it will entail and in the light of any constraints which may affect it. The time corresponding to each of the minutely analysed motions is then read from tables, and the job time is obtained by adding all the individual times.

All these systems entail a fairly lengthy period of intensive training under expert guidance, and trainees are unlikely to be able to apply the methods satisfactorily unless they are already skilled and experienced in methods analysis before undertaking the special instruction. The systems require a good deal of work for their application, often much more than that involved in direct time study. To apply one of the basic systems to a manual task taking only one minute to perform may require as much as 100 minutes of analysis and computation.

These disadvantages have led to the development of a number of simplified systems which, although rather less accurate, take far less time to learn and to apply. It is claimed for some of the simpler systems that they can be taught to trainees who have not first had thorough training in the parent systems from which they have been developed.

Whatever the system, the rules which govern its application must be thoroughly understood before any attempt is made to apply it. The rules differ from system to system. Some tabulated time values incorporate relaxation allowances, while in

other systems allowances have to be added after the motion times have been derived before the final standard time can be established.

For some time after predetermined motion time systems were originally launched they were regarded with suspicion by management, unions and work study men alike, but they are generally coming to be more widely accepted in both the United States and Europe.

The advantages claimed for them are broadly those offered by synthetic times, with the following in addition:

1. Once personnel have been trained to use them the tabulated values are ready for immediate use and do not have to be built up within the individual organisation.

2. They are universal in character and not confined to a limited number of elements. Time standards for most of the physical activities carried out in the average factory can be built up from the basic times.

3. They are applicable anywhere, so that, in theory, identical jobs done in different factories should have identical time standards if the work study men setting them have been properly trained.

4. They focus attention on the method before the time can be set and offer a more precise means of recording than any other existing system.

5. They are of value in training operators in new methods, since the paths of movement are precisely described.

6. Because of the detailed breakdown, changes in method can immediately be identified.

The claim under item (3) does not appear to be wholly borne out in practice. The majority of the most widely used systems were developed in the United States and Canada, under conditions ruling there, and in certain European applications it has been found necessary to increase the original times somewhat by multiplying them by a constant factor. It is now thought that the difficulties may have derived from the use of different terminologies in Europe and North America, and to differences between the rating scales in use in the different areas. F. J. Neale1 suggests that American times may have to be increased by approximately 11 per cent. to satisfy European conditions. Considerable experiment and study may be needed before it is known what adjustments may be appropriate in other parts of the world.

There are, however, a number of disadvantages:

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Other Techniques

(1) Some research workers have questioned whether it is valid to add times for individual small motions in the way required by the systems, and have pointed out that the time for a particular motion may be influenced by the motions preceding and following it.

(2) The systems are generally restricted in their application to jobs which are repeated very many times and are generally uneconomic for non-repetitive jobs and small batch lots. This drawback is somewhat lessened if one of the newer, simplified systems is used.

(3) The systems have limitations when applied to restricted work and are thus not universally applicable throughout every organisation.

One of the most important contributions that predetermined motion time systems have made is undoubtedly their effect of forcing work study men to give

FIGURE 94. APPLICATION OF M.T.M. ANALYSIS TO OPERATION OF CUTTING GLASS TUBES
(Improved Method)

<table>
<thead>
<tr>
<th>PART: Glass tube 3 mm diameter</th>
<th>OPERATION: Cut to length</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESCRIPTION – LEFT HAND</td>
<td>No.</td>
</tr>
<tr>
<td>Push tube forward in jig</td>
<td>2x</td>
</tr>
<tr>
<td>Advance tube in hand</td>
<td></td>
</tr>
<tr>
<td>Push tube against stop</td>
<td></td>
</tr>
<tr>
<td>Hold tube in jig</td>
<td>6.7</td>
</tr>
<tr>
<td>Rotate tube</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>38.8</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold tube</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>18.1</td>
</tr>
<tr>
<td>TOTAL TIME</td>
<td>70.1</td>
</tr>
</tbody>
</table>

LH = Left hand    RH = Right hand    TMU = Time Measurement Units

Note: The subsequent introduction of a new type of file, with a keener and longer-lasting cutting edge, resulted in a further increase in productivity of about 30 per cent.
close attention to work methods before setting time standards. In the past there has tended to be over-emphasis on getting out time standards (generally in connection with incentives) without much attention being paid to method study other than a general putting right of the more obvious instances of wasted time or effort. This often left the precise work content of the operation to the discretion of the operator, which tended to make either for performances on his part that were uneconomic from the point of view of management or for reduced output.

An outstanding example of the use of predetermined motion time standards in Europe is the adaptation of the work factor system in the locomotive and rolling-stock repair shops of the northern section of the French National Railways.

An example of an element analysis using the methods-time measurement system (M.T.M.) is shown in figure 94. The operation is that of cutting 3 mm diameter glass tubes into short lengths, which was discussed and charted in Chapter 11.

The figure shows an analysis of the improved method, for which a time of 0.04206 min is built up. A similar analysis of the original method resulted in a time of 0.09516 min, so that the improvement represents a reduction of 56 per cent. The note at the foot of the figure shows that further critical examination resulted in a still further increase in productivity.
1. RANGE OF ACTIVITIES

The range of activities which a well-established work study department may be called upon to undertake will depend to a large extent on what other technical staff departments or sections there are in the organisation. In most instances, however, the work study department will be expected to carry out the following:

(a) Method studies of existing jobs and operations, leading to the installation of improved methods.

(b) Work measurement, and the determination of time standards.

(c) Examination of proposed changes affecting the work of the operatives, and in particular the preparation of plant and machine layout schemes for any extensions or reorganisations.
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(d) The routine compilation of control statements for supervision and for management, in so far as these are concerned with the use which is made of workers' time and the output produced.

(e) Design and installation of incentive schemes for workers.

2. THE PLACE OF THE WORK STUDY DEPARTMENT IN THE ORGANISATION OF AN ENTERPRISE

As was said in Chapter 4, line management rarely has the time to devote to the uninterrupted and prolonged studies which are necessary to enable work study to produce really satisfactory results. This being the case, the work must be delegated to a specialist, who may, as his work develops, form a special department.

Work study is a service to the management of an enterprise and, as such, must be a staff and not a line activity (see page 37, footnote). The position of the head of the work study department in relation to his fellow members of the senior staff depends on a number of factors, including—

(a) The industry and the nature of the work carried out;

(b) The size of the organisation;

(c) The type of organisation, including any features which may be traditional to the industry and whether the company is owner-managed or is a company managed by professional managers;

(d) The qualifications, experience and personality of the man himself;

(e) The qualifications and competence of the heads of the departments with whom he is most likely to be concerned.

It is thus only possible in this section to lay down the most general principles for determining the position which the head of the work study department should occupy.

Broadly speaking, since his role is mainly advisory, the person in charge of work study should occupy a sufficiently high position to ensure that his advice will be listened to with respect and acted upon. In medium-sized and large companies where there is already a fairly high degree of specialisation, and where the works executives—works manager, superintendents and foremen—are professionally and technically qualified and have wide experience, it is generally satisfactory for him to report to the works manager or chief production executive, whatever his title. If the industry is one where technical knowledge is demanded at all levels, such as engineering, there may be a chief industrial engineer in charge of work study, process planning and tool design. He may or may not be the expert in
In a small company or one where the works staff is not technically qualified, as is sometimes the case in industries where the technical content of the work is not high, it is often better that the work study man should be directly responsible to the president or managing director and on a level with the works manager and other departmental heads. In this way he can be sure of direct access to the man whose decisions really count. Whatever the position of the head of the work study department, the important thing is that he should be so placed that he can be reasonably sure that his recommendations, if sound, will be carried out, otherwise his specialised knowledge will be wasted and he himself will be the subject of acute frustration.
3. STRUCTURE OF A WORK STUDY DEPARTMENT

Many of the people who read this book will do so in conjunction with a course of instruction in work study, perhaps conducted by a national productivity centre, a technical university, or other institution teaching the subject in their country. They may then be expected to return to their firms or organisations with the responsibility of introducing work study into them, in the first stages without the assistance of trained personnel. Their departments will consist of one man only—themselves.

This being the case, very little organisation will be needed. Nevertheless, work study, and particularly work measurement, contains a great deal of routine work which can be done by intelligent clerks, untrained in work study itself. The speed of the application will be increased if the work study man is given clerical assistance at an early stage for such work as—

(a) preparing the layouts for flow diagrams from the work study man’s sketches, cutting out templates, making string diagrams from the data provided and doing the calculations associated with process charts;

(b) when time study is started, extending the studies and doing other calculations in connection with them;

(c) filing and maintaining the necessary records.

Such a clerk should be able to learn to multiply and divide on a slide-rule without any difficulty. It is not necessary to go into long explanations of the theory of the slide-rule to teach its use to comparatively uneducated people provided that the latter are accurate and painstaking. The drawing of simple layout diagrams to scale on squared paper does not require a high degree of intelligence or skill, simply care and accuracy.

When an incentive scheme is introduced the calculation of performances will be the responsibility of the work study department. This is certainly something that can be done by a clerk. As soon as possible the financial side of the calculations should be handed over to the wages department, since it is important to maintain a clear distinction between work study and wage policy. Work study should be thought of solely as a means of improving methods and setting objective standards of performance. However, in the early days of an application, or where the wages department is not capable of undertaking the work, it may have to be done in the work study office. This should, however, be avoided wherever possible.

As the department grows and other work study men are added to it, the head of the department may wish to consider whether some specialisation is not desirable. While he himself must have a complete knowledge of both method study and work measurement—and he should certainly ensure that his juniors have a good knowledge of both techniques—he may decide that his first assistant should specialise
in method study while the next should specialise in time study. Whether he does so or not will depend very much on the relative amount of work to be done in each field, and this in turn will depend on the nature of the processes carried out in the works and, possibly, on questions of management policy, e.g. the extent to which incentive schemes are to be installed.

There is a good deal to be said for this specialisation, from several points of view. One of these, in the opinion of a number of well qualified people, is that there are advantages in separating out method study from time study, since time study may at first be regarded with some suspicion by the workers, as being directly concerned with their earnings or the amount of work they may be called upon to do. Method study, on the other hand, is largely concerned with solving problems of a technical nature and will often bring improvements in working conditions, and should thus gain their co-operation and support.

Additional clerical assistance should go hand in hand with increases in specialist staff in order that the specialists may be relieved of routine clerical work. As time standards are developed and incentive schemes applied progressively through the organisation there will inevitably be a certain amount of work for the specialists to do in checking methods and standards on the shop floor, dealing with queries from the workers, and investigating the causes of low performance or other anomalies. If the further progress of work study is not to be slowed almost to a standstill it will be necessary either to increase the number of specialists or to relieve them of as much clerical work as possible—perhaps both.

The advantages of a room or corner of a shop where new methods can be tried out have already been discussed briefly at the end of Chapter 11. If such a room can be obtained and one or two operatives employed, it is desirable that they should be transferred to the department for the period that they are working there, and it is important that they should be made to feel part of it. Work study can often produce quite spectacular results for comparatively little effort and, consequently, can be very exciting. Let the operatives in the department share in the excitement and feel, as most work study men do, that they are doing work of special value.

**Equipment**

The work study office should be near the workshops or working area, but not so near that it is subject to a great deal of noise. Many of the calculations and analyses demand considerable concentration, and anyone who has tried to work up a study or examine a methods problem in the immediate neighbourhood of a heavy press shop or a weaving shed knows that it can impose quite a strain, even when one is not fully conscious of the noise. In method study it is often necessary to discuss possible means of improvement with other members of the staff, sometimes at some length. Conversations carried out against a background of machine noise become very exhausting.
The Work Study Department

The office should be furnished with either tables of a reasonable size (say $1.5 \times 1 \text{ m}$), or with built-in workbenches round the walls of sufficient length to enable all the members of the staff to work in comfort. Each member should have a small drawer for personal belongings, preferably with a lock, so that he can lock up his stopwatch, slide-rule, etc., at night. There should also be a large table or bench to spread plans and diagrams on. Normal office furniture for a small office should include—

- a chair for each member of the office and two or three spare ones;
- a filing cabinet, locking;
- a cupboard for stationery;
- a shelf for books;
- a typewriter;
- a drawing board, tee-squares, set-squares, rules, etc.;
- a board for the display of charts.

Larger offices may require a small hand-operated calculating machine. Time study equipment and stationery have already been detailed in Chapter 14.

Workers’ Nominees

The work of the department will usually be greatly facilitated if it can be arranged for the workers in sections or departments where studies are to be made to nominate one or more of their number to serve for a period in the work study office, where they will receive the same training as the regular work study staff. This commendable practice was referred to in Chapter 5, Section 4. It has proved of inestimable benefit whenever it has been adopted. It is reported that the inclusion and training of a nominee of the workers on the staff of the work study department is an important part of the agreement signed between the National Federation of Employers and the National Trades Union of Norway in 1947. This agreement has been followed by similar ones in Sweden and Denmark, and the practice has been a common one in the United Kingdom for many years.

The abilities and attributes which are necessary in a work study man were discussed in Chapter 5.

4. ORGANISATION OF WORK

Filing

It is vital to the success of any work study department, however small, that an adequate system for identifying studies and records of all sorts, and for filing and
The Work Study Department

retrieving them, should be instituted right from the outset. Every study should have a number assigned to it and the main details which describe the study, including information about where it is filed, should be entered in the register of studies. Large departments may need to keep several registers, one for method studies, another for time studies, and so on. Some of the largest departments, however, prefer to maintain a single central register, even though they are producing many studies a day, preferring to extend the usefulness of the one register by cross-referencing rather than risk the possible loss of control which may develop when several different records are kept, perhaps by different clerks.

If it is intended that synthetic data shall be extracted from the studies to facilitate the work of determining time standards at a later stage in the application of work measurement procedures in the organisation it is important to assign the responsibility for making such abstractions to one of the specialist work study men at the beginning. If the work is not carried out as studies go along it becomes extremely difficult—if not impossible—to build up all the synthetic data that would otherwise have been available by a special exercise carried out long afterwards.

Care of Stopwatches

Every work study department should have at least one spare stopwatch. Many departments keep a master watch as well—one which is not used for normal study-work but is maintained as a standard against which the others may be checked. The master watch is returned to a reliable watchmaker regularly for checks on its accuracy, and all watches in use are checked against it at least weekly. This may be done by winding both watches fully, and then starting them at the same instant. The simplest way of doing this is to hold the two watches stem to stem, pressing them against each other so that both are stopped, and then separate them smartly. When the master watch has run for exactly 30 minutes the other is stopped, and any error read off. It should not exceed three-hundredths of a minute.

Watches should be checked from time to time while in service to see that the hand flies back exactly to zero when the stem is pressed, and not to some position on either side of zero. The flyback motion should be quite smooth and without pause. It should be tried from at least three positions on the dial, for the hand moves one way if stopped while over one part of the dial, and the other way if stopped while the hand is over the rest of the face.

Maintaining Standards of Rating

It is important that standards of rating be maintained and that these standards be consistent as between the different members of the work study staff within the same organisation. It is necessary, therefore, to check the rating of each studyman at regular intervals.
There are various comparatively simple ways of ensuring this. Among them are the following:

(a) Two or more studymen study the same operator at the same time but independently and compare notes when the study is complete. Tests should be made on operators of various levels of speed and skill.

(b) By making a fresh study of a job which has been long established and whose time standards are well proven. Care must be taken to reassure the operator that no change in the time standards will be made as a result of the study, and to explain the purpose of the study.

(c) By production studies of an operator working to established time standards. The observer rates the operator every half-minute over

**FIGURE 96. RATING-TIME GRAPH**

![Rating-Time Graph](image-url)
a long period (possibly half-a-day or a day) and then compares
the average performance calculated from his observations with
that actually achieved by the operator as measured by his output
over the period. Ineffective time must be carefully noted and
excluded.

In addition to these directly comparative methods there are various graphical
methods which can be easily carried out without special resources. Two of these
are—

(a) The rating-time graph. This is useful where a single element can be
rated on several operators. All the actual times of the element are
plotted against the ratings as shown in figure 96.

A mid-point is selected (in the example shown the mid-point is
0.12 min at 85 rating) and the equivalent times at high and low
ratings are worked out (in the example 0.08 min at 112 rating and
0.20 min at 45 rating). These two points are entered on the graph
and a curve (which will be a hyperbola) plotted through the three
points. If the observer has been consistent in his rating at all
levels of performance his points will follow the curve in the manner
shown.

(b) Where the exact ratings of an element carried out at different speeds
can be obtained, another graphical method of checking accuracy
and consistency can be used. This is possible where the standard
performance can be obtained in terms of time, as for a man walking
over a measured distance or dealing a pack of 52 playing cards.1
Times of performances at ratings above and below the standard can
then be calculated.

Observers are asked to record their ratings in a table similar to that
shown below the chart in figure 97. The actual ratings calculated
from the times taken are then filled in below them and the differences
recorded. This gives an indication of the amount of error and whether
it is systematic or not. The observers' ratings are then plotted on the
chart and a straight line drawn between the points so that they are
evenly distributed about it. If a diagonal is now drawn across the
chart upwards from left to right the slope of the line will indicate
the degree of consistency of the ratings. If the slope is steeper than
that of the diagonal, it means a tendency to rate too high at higher
levels of performance and too low at the lower levels; if it is flatter
the reverse is the case.

This method can also be used with films of elements of factory opera-
tions projected at a standard speed.

---

1 The time required to walk 20 metres at standard performance is 0.187 min. The standard performance
time to deal a standard pack of 52 playing cards into four equal heaps is considered to be 0.375 min.
FIGURE 97. RATING EXERCISE

<table>
<thead>
<tr>
<th>TEST No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESTIMATED RATING</td>
<td>80</td>
<td>105</td>
<td>140</td>
<td>95</td>
<td>75</td>
<td>65</td>
<td>85</td>
<td>105</td>
<td>120</td>
<td>85</td>
</tr>
<tr>
<td>ACTUAL RATING</td>
<td>79</td>
<td>107</td>
<td>145</td>
<td>95</td>
<td>78</td>
<td>56</td>
<td>79</td>
<td>104</td>
<td>124</td>
<td>82</td>
</tr>
<tr>
<td>DIFFERENCE</td>
<td>+1</td>
<td>-2</td>
<td>-5</td>
<td>0</td>
<td>-3</td>
<td>+9</td>
<td>+6</td>
<td>+1</td>
<td>-4</td>
<td>-3</td>
</tr>
</tbody>
</table>

SYSTEMATIC ERROR

flat
There are other methods of training in and checking rating by the use of films, but, since films are not widely available to individual enterprises, these need not be discussed here. Most productivity centres are equipped with projectors and supplied with training films.

**Training of Work Study Staff**

The basic training of work study staff is best accomplished by sending them to a regular training course run by the local management development or productivity centre, or other technical institution, whenever this can be arranged. Such centres have the gadgets and training aids which make teaching more effective, and which it would rarely be economical, for the smaller firm at any rate, to maintain for the small number of trainees likely to be required.

If training of the bulk of the staff has to be carried out in the enterprise, every effort should be made to have at least one member trained externally so that he can copy the exercises and teaching methods employed by an established institution. Some notes on the use of this book as an aid to teaching will be found in Appendix 1. Rating practice should not be attempted until the trainees have become thoroughly familiar with the manipulation of the stopwatch, which can be achieved by simple exercises. A good deal of attention will need to be given to practice in rating, for this is the feature of time study which takes longest of all to master.

**Training Activities of the Work Study Department within the Enterprise**

As the head of the work study department and his staff gain experience and confidence they will be able to undertake training activities within the organisation. As already stated (in Chapter 5), it is of the greatest importance that managers, supervisors and workers' representatives should have a proper understanding of work study.¹

Neverthelesss, it is highly desirable that information on the purpose and practice of work study be conveyed to other members of the enterprise as soon as possible. If there are no suitable courses at productivity centres or technical institutes in the vicinity, small informal meetings at which brief talks can be given by the work study staff, followed by questions and general discussion, will serve a very useful purpose and are easier to conduct.

¹ Syllabuses of courses for these groups are to be found in Appendices 2 and 3. These, however, have been merely put in as examples; they are courses which have been devised and conducted by men very experienced in both the practice and teaching of work study, and it is not recommended that attempts should be made to put on similar courses without similar experience.
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Training or retraining the operatives in improved methods is one of the jobs which normally falls to the lot of the work study department, but it is unlikely that training in complex operations or refined movements can be undertaken unless a member of the department has undergone a special course. This should only be undertaken after prolonged experience in the field of methods improvement. Pre-determined motion time systems are a help when analysing extremely rapid and complex motions. The establishment of a methods laboratory helps in developing training methods in operations of a less complex nature, since the work study staff gain an insight into the nature of the physical activities involved.

Other Activities of the Work Study Department

The trained work study man entering or returning to an organisation may well find himself the only member of the senior staff without direct operational responsibility. His value to the organisation lies precisely in his being free from such responsibility and so having the time to concentrate on the study of a single problem—even a single operation—at a time without interruption. Managers who are unaccustomed to the idea of a “spare man” may not take kindly to this. They will regard him as “unproductive”. Nevertheless, he must do all in his power to avoid being given an operating department to look after.

There are two principal ways in which the work study man can overcome this attitude on the part of the management and get himself accepted not merely as a useful but an essential member of the organisation. The first is by persuading his directors and members of top management to learn something about work study, either by attending appreciation courses given at productivity centres and other institutes outside the firm or by himself organising appreciation courses within the organisation with the aid of outside experts. The second is by keeping extremely careful records of performance on each job both before and after the application. In this way the improvements in performance can be readily appreciated and, translated into terms of reduced costs of production or increased output, will provide striking evidence of the value of his work.

Many enterprises make a practice of budgeting the annual cost of their work study departments and using the budgets as the basis of targets for the direct savings which they expect the departments to achieve by applying work study techniques. It is common to set the direct savings target at three times the total annual cost of the department, and to expect fresh savings to be made at this rate every year.

Once the work study staff have proved their worth, the danger may be that the management may wish to turn them onto problems outside their own field. Here it will be necessary to steer a middle course. Many problems may come to light as a result of work study investigations, and it may be necessary to solve them before the work study application can proceed. Hold-ups in the flow of work or materials
revealed as a result of study are an example of this type of problem. It is a good thing from the points of view of both management and the work study staff themselves that they should occasionally have to deal with problems outside their own immediate field, but it is a bad thing if work study application has to be held up for a long time as a result.

As a working rule it is suggested that work study men should try not to allow their energies to be deflected on to problems which do not affect the efficiency or progress of the work study application directly until after the initial stages of the application have been completed. Thereafter they may be able to turn their attention to other management problems, if requested, since maintaining the work study application will become more a matter of routine.
NOTES ON THE USE OF THIS BOOK
AS AN AID TO TEACHING

Courses on work study are likely to be mainly of two types, namely—

(a) appreciation courses for top management, supervisors and/or workers' representatives designed to enable the participants to acquire a good understanding of the nature and purpose of work study without being expected to practise it; and

(b) courses for middle management and works executives who may be required to apply it or to take charge of its application when they return to their organisations. Representatives of workers may also be expected to take part in these courses.

Courses of type (a) may well be associated with lectures in general management or with other industrial engineering subjects.

Chapters 2 and 3, which deal with the effect of general management techniques on productivity, are self-contained and can be used independently or in conjunction with either type of work study course.

The following is a list of possible topics for a course of type (a) and a list of references to the chapters and sections of this book where the material may be found.

Appreciation Course for Top Managers, Supervisors and Workers' Representatives

(about 8 lectures of 1-1½ hours each)

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Subject</th>
<th>Chapter</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nature and value of work study</td>
<td>4</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td></td>
<td>Method study: objects—basic procedure—selection of work</td>
<td>7</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td></td>
<td>Recording—the outline process chart</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Use of the “questioning sequence”; example of a flow process chart</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Layout and handling; the flow diagram in association with flow process charts</td>
<td>9</td>
<td>1, 3, 4, 5</td>
</tr>
<tr>
<td></td>
<td>Principles of materials handling</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Movement of workers in the shop; the string diagram</td>
<td>10</td>
<td>1, 2</td>
</tr>
</tbody>
</table>
Appendix 1

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Subject</th>
<th>Chapter</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>The operator at the workplace; the multiple activity chart</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>The two-handed process chart</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>The principles of motion economy</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Notes on workplace layout</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Installing the new method: standard practice; gaining experience</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Work measurement; definition and purpose; uses and basic procedure</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time study: definition; equipment</td>
<td>14</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td></td>
<td>Selection of work</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Steps in making a time study</td>
<td>15</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td></td>
<td>Elements</td>
<td>15</td>
<td>6, 7</td>
</tr>
<tr>
<td>5</td>
<td>Stopwatch procedure</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Rating; the concept of the qualified worker and the &quot;average worker&quot;</td>
<td>16</td>
<td>1, 2</td>
</tr>
<tr>
<td></td>
<td>Standard pace; comparing observed pace with standard</td>
<td>16</td>
<td>3, 4</td>
</tr>
<tr>
<td></td>
<td>Rating scales</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Extension</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Study summary; selection of basic times; variable elements; analysis of studies; contingency allowances; relaxation allowances</td>
<td>17</td>
<td>2, 4, 7, 10, 11, 13</td>
</tr>
<tr>
<td>7</td>
<td>Time standards for work with machines</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Example of a time study</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The issue and use of time standards</td>
<td>20</td>
<td>(in outline)</td>
</tr>
<tr>
<td></td>
<td>Production study</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Activity sampling</td>
<td>21</td>
<td>2</td>
</tr>
</tbody>
</table>

For a course of type (b) the following programme is recommended. Practical periods would be additional.

Course for Middle Management and Works Executives Having Responsibility for Introducing Work Study into Their Organisations

(about 26 lectures of 1-1½ hours each)

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Subject</th>
<th>Chapter</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Productivity and management techniques</td>
<td>2, 3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>The nature and value of work study</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>The human factor in the application of work study</td>
<td>5 (less section 5)</td>
<td></td>
</tr>
</tbody>
</table>

Note: The way in which this topic is handled will depend on the lecturer's experience of local conditions, but the lecture should not be omitted as it is important that the trainee should recognise from the outset that success in the application of work study depends more than anything else on obtaining the willing co-operation of all concerned.
<table>
<thead>
<tr>
<th>Lecture</th>
<th>Subject</th>
<th>Chapter</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Working conditions</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note: This lecture may be given either at this point or at the end of</td>
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<tr>
<td></td>
<td>the series, as the lecturer prefers.</td>
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</tr>
<tr>
<td>5</td>
<td>Method study</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Method study: Recording</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Note: Further examples of outline process charts may be made up</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>from work of a type familiar to trainees.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>The flow process chart</td>
<td>8</td>
<td>1 (the</td>
</tr>
<tr>
<td></td>
<td>Note: At least one period of practice in the making of flow process</td>
<td></td>
<td>flow process chart), 2, 3</td>
</tr>
<tr>
<td></td>
<td>charts is recommended after this lecture.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Factory layout</td>
<td>9</td>
<td>1-6, 9</td>
</tr>
<tr>
<td></td>
<td>Note: Depending on the importance attached to layout in connection</td>
<td></td>
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<tr>
<td></td>
<td>with the particular course, Lecture 7 may be spread over two periods</td>
<td></td>
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<tr>
<td></td>
<td>with a very detailed discussion of the example in Section 9 or may be</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>telescoped with Lecture 8.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Materials handling</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Note: Insert examples of simple materials handling equipment which can</td>
<td></td>
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<tr>
<td></td>
<td>be made locally at little expense.</td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>Shop layout and the movements of workers</td>
<td>10</td>
<td>1-3</td>
</tr>
<tr>
<td></td>
<td>Note: A demonstration model of a string diagram can be worked out and</td>
<td></td>
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<tr>
<td></td>
<td>made up. The man-type flow process chart is so similar to the</td>
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<tr>
<td></td>
<td>outline process chart that it should not be necessary to spend</td>
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<tr>
<td></td>
<td>much time on it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Multiple activity charts; travel charts</td>
<td>10</td>
<td>4, 5</td>
</tr>
<tr>
<td>11</td>
<td>Methods and movements of the workplace</td>
<td>11</td>
<td>1-3</td>
</tr>
<tr>
<td>12</td>
<td>Workplace layout</td>
<td>11</td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>13</td>
<td>Further discussion on workplace layout with notes on micromotion study</td>
<td>11</td>
<td>7-10</td>
</tr>
<tr>
<td>14</td>
<td>Installing and maintaining the improved method</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Work measurement—purpose, uses and basic procedure</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Time study equipment</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Time study—preliminary information</td>
<td>15</td>
<td>1-5</td>
</tr>
<tr>
<td>18</td>
<td>Elements and the use of the stopwatch</td>
<td>15</td>
<td>6-9</td>
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<tr>
<td></td>
<td>Note: At least one, and possibly two, practice periods should be given</td>
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<tr>
<td></td>
<td>after this lecture in breaking down jobs into elements and using the</td>
<td></td>
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<tr>
<td></td>
<td>stopwatch.</td>
<td></td>
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<tr>
<td>19</td>
<td>Rating</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note: At least two periods after this lecture should be devoted to</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>rating practice and the lecture should include a demonstration.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Study summary; extension; selection of basic times; analysis of studies</td>
<td>17</td>
<td>1-7</td>
</tr>
<tr>
<td>21</td>
<td>Contingency allowance and relaxation allowances</td>
<td>17</td>
<td>10-13</td>
</tr>
<tr>
<td>22</td>
<td>Time standards for work with machines</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Discussion of the example of a time study</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>The issue of time standards—work specifications</td>
<td>20</td>
<td>1, 2</td>
</tr>
<tr>
<td></td>
<td>Note: Examples of job specifications suitable to the industries or</td>
<td></td>
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<tr>
<td></td>
<td>type of work of the course should be drawn up and discussed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>The use of time standards</td>
<td>20</td>
<td>3-8</td>
</tr>
</tbody>
</table>
Appendix 1

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Subject</th>
<th>Chapter</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Production study</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Note: Examples from the industries concerned should be given if possible.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Activity sampling (with examples from the industries concerned if possible)</td>
<td>21</td>
<td>2, 3</td>
</tr>
<tr>
<td>(Optional) The other techniques described in Chapter 21 may be the subject of an additional lecture if considered desirable.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>The organisation and staffing of a work study department</td>
<td>22</td>
<td>4</td>
</tr>
</tbody>
</table>

It is not, of course, suggested that the texts should be followed word for word. Lecturers will naturally wish to add their own comments or experiences or to vary practices recommended in the book to suit local circumstances or their own preferences. If, however, recommendations are made which are at variance with those given in the book (such as recommending flyback rather than cumulative timing) full explanations should be given in order that trainees should not be confused.

If the book is to be used for a full-scale work study course it will probably be found that large parts of it, especially in the section on method study, can be employed more or less as they stand. The parts to be given the greatest emphasis will depend on the industry from which members of the course are drawn: for example, in a light industry which has mainly bench work greater stress would be put on the principles of motion economy and less on layout and handling.

Some lecturers may find it preferable not to issue copies of *Introduction to Work Study* to trainees until after the end of the course so that they may derive the greatest benefit from the lectures and association with the lecturer. Most of the examples of method study given in the book lend themselves to discussion. The "improved methods" given are by no means final, and trainees may often be able to suggest greater improvements which they can be asked to work out for themselves. Every effort has been made to provide enough information with each example to enable this to be done. The more examples that can be worked out before trainees return to their organisations for practical periods of work the better; any additional periods spent on local examples will give them greater confidence when they have to start work on the shop floor.
EXAMPLE OF AN APPRECIATION COURSE
IN WORK STUDY FOR TOP MANAGEMENT

Based on Courses Conducted by the Engineering and Allied Employers’
(West of England) Association

First Day

Morning.
- Opening of the course.
- Work study as a tool of management (1½ hours). The scope and value of work study; elimination of wasted effort; measurement of work; correction of wage anomalies; better management control; co-ordination within the organisation; selection and training of staff; effective use of work study.

Afternoon.
- Developing better methods (1½ hours). The purpose and scope of method study; methods of observation; analysis and reconstruction; installation and maintenance; examples of applied method study illustrated by films and slides; discussion.
- Practical exercise in the use of method study (1½ hours). The flow process chart and its uses; making a flow process chart of a simple operation from a film; developing the improved method; discussion.

Evening.
- Work study films and discussion (as long as desired).

Second Day

Morning.
- Work measurement by the use of time study (1¼ hours). Objectives of work measurement; element timing; assessing operator performance; allowances for relaxation, etc.; procedure in making a typical time study; discussion.
- Rating (1½ hours). Variations in operator performance; range and distribution of human capacities; establishment of standard performance; practical exercise and film; discussion.

Afternoon.
- The wage structure (1 hour). Converting time into money; incentive schemes; fair rates per hour through job evaluation; discussion.
- Concluding discussion. How can management make effective use of work study?
EXAMPLE OF A SHORT COURSE IN WORK STUDY
FOR SUPERVISORS

The following is the syllabus of the standard course comprising 14 sessions of 1½ to 2 hours each conducted by the Bureau des temps élémentaires (French Central Work Study Organisation) in seven cities during 1953-54.

   The evolution of industry; division of labour; aims of the enterprise; functional organisation.

2. The Study and Simplification of Work.
   Work study; motion economy; standardising methods and workplace layout; improvements to tools and machines.
   Work simplification (method study) and the improvement of the process; analysis of existing methods: the questioning technique; prerequisites for successful application; working conditions. Fatigue; physiological factors; psychological fatigue; selection, placement and training of workers.
   The application of method study in the factory.

   The purpose of work measurement; how it affects the foreman.
   Timing procedures and the judgment of performance.
   Setting time standards.

   Process planning, its purpose and value; the planning office; planning techniques.
   The application of work specifications; liaison between the works and the planning office.

5. Conclusion.
   The evolution of work study and its bearing on industrial relations.
   This course, which was successfully applied in France for some years, shows a broad approach to the education of supervisors in work study and its relation to their own jobs and to the working of the factory as a whole. Each session includes time for discussion and, where appropriate, films, demonstrations and studies of actual examples.
COURSE IN PRODUCTIVITY
IMPROVEMENT TECHNIQUES
FOR MIDDLE MANAGEMENT

Organised by the Egyptian Productivity and Vocational Training Centre

This course followed a series of appreciation courses for top management which were held in Cairo and Alexandria during the first year of the Centre's life.¹

The object of the course was to give intensive training in some of the techniques discussed in the appreciation courses. The main emphasis was laid on method study, which, as experience indicates, enables practical results to be obtained relatively quickly if properly applied. Other important subjects such as organisation, production planning and control, wage structures and costing were also included.

Three of these courses were completed between October 1955 and September 1956. The experience gained in these courses was embodied in the syllabus given below, which is that of the fourth course, given in October 1956.

The courses were divided into three parts, the first lasting four weeks and consisting of theoretical and practical training in the lecture room and laboratory. Students then spent four weeks on practical work in their own plants under the guidance of the staff of the Centre and I.L.O. experts attached to it. The third part consisted of a final seminar lasting a week during which the students presented case studies of their work and discussed the results achieved.²

Before students were accepted the employers concerned were required to give an undertaking that they would make permanent arrangements in their plants (such as the setting up of work study departments) whereby students would be enabled to continue putting into practice what they had learned. The number of participants on each course was limited to a maximum of 20; the total for the four courses was 73.

**Syllabus**
*(9 weeks)*

**FIRST PART**
*(4 weeks)*

Lectures

1. *Introduction.*
   
   (a) Introductory lecture.
   
   (b) Main factors affecting productivity.

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¹ The Centre has since been converted into a department of the Ministry of Industry.
² An example of the work of the trainees is given in Chapter 10 (feeding bones to a crusher in a glue factory).
Appendix 4

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c) Waste, the enemy.</td>
<td>1</td>
</tr>
<tr>
<td>(d) Principles of organisation and general management.</td>
<td>4</td>
</tr>
</tbody>
</table>

   (a) Basic procedures.
   (b) Working conditions including safety.
   (c) Selecting the job, recording and examining the facts, developing the best methods.
   (d) Layout and materials handling.
   (e) Movement of workers.
   (f) Methods and movements at the workplace.
   (g) Jigs, tools and fixtures.
   (h) Installing and maintaining the new method.
   (i) Work specifications (1).

   (a) Basic procedures.
   (b) Equipment used.
   (c) Selecting the job.
   (d) Making the study.
   (e) Rating.
   (f) Examining the study and calculating the standard time. Allowances.
   (g) Work specifications (2).
   (h) Production studies.
   (i) Synthetic times.

4. Wage Structures and Payment by Results. | 2     |

5. Other Management Techniques.
   (a) Simplification, standardisation and specialisation of design.
   (b) Quality control.
   (c) Production planning and control.
   (d) Stores and stock control.
   (e) Costing.
   (f) Plant maintenance.

6. Training.
   (a) Supervisory training.
   (b) Selection and training of operatives.

7. Conclusion.
   (a) How to write a report.
   (b) Concluding lecture.

Practical Exercises
1. Practical Exercises and Demonstrations.
   (a) Method study.
   (b) Time study. | 50 6 |

2. Films. | 4     |

Other Activities
1. Free Discussion. | 1 |
2. Weekly Tests. | 8 |

Total . . . | 120 |
SECOND PART
(4 weeks)

Students' Practical Work in Their Own Plants under Supervision.

THIRD PART
(1 week)

Discussion of Case Studies and Final Examination.
GLOSSARY OF TERMS USED

A. MANAGEMENT TERMS

Budgetary Control (Chapter 20).
A means of controlling the activities of an enterprise by carefully forecasting the level of each activity and converting the estimates into monetary terms. The actual cost of or revenue from each activity is checked against the estimates.

Consumer Research.
The collection, recording and analysis of information obtained from purchasers and users relating to specified products or services together with their suggestions for making those products or services more suitable to their requirements.

Incentive Scheme.
Any system of remuneration in which the amount earned is dependent on the results obtained, thereby offering the employee an incentive to achieve better results.

Inspection.
The function by which the control of quality is maintained. In the industrial sense it is the application of tests with the aid of measuring appliances to discover whether a given item or product is within specified limits of variability.

Maintenance (in the management sense).
The systematic servicing and repair of plant, equipment and buildings with a view to preventing breakdowns while in use.

Management.
The organisation and control of human activity directed towards specific ends.

Management Techniques.
Systematic procedures of investigation, planning and control which can be applied to management problems.

1 Most of these terms appear for the first time in Chapter 3. When this is not the case the chapters in which they occur are given in parentheses.
Appendix 5

Marketing Policy (Chapter 2).

The whole policy of an enterprise regarding the marketing of its products or services. It includes questions relating to the range of goods or services to be offered, markets to be entered, price ranges, selling methods, distribution and sales promotion.

Market Research.

The gathering, recording and analysing of all facts about problems relating to the transfer and sale of specified goods and services from producer to consumer.

Material Control.

Procedures and means by which the correct quantity and quality of materials and components are made available to meet production plans.

Operator Training.

The systematic training or retraining of workers in manual skills with a view to ensuring sound and uniform working methods.

Personnel Policy.

The whole policy of an enterprise towards its employees. It embraces methods of remuneration, welfare services, consultation, relations with unions, social security and all other matters in which the attitude of the employer can affect the lives and well-being of those employed.

Pilot Plant.

A small-scale plant set up after the development of a process or product in the laboratory to investigate problems likely to occur in operation on a commercial scale.

Process Planning.

The detailed planning of the processes of manufacture necessary to convert raw material into finished products before commencing operation. The term originated in the engineering industry.

Process Research.

Research into the nature and characteristics of a given manufacturing process.

Product Development.

The stage, usually between design and large-scale production, during which units of the product are tested and studied with a view to improving performance and ease of manufacture.

Product Research.

Research into the nature and characteristics of a product or potential product in relation to the functions it has to or may have to perform.

Production Planning and Control.

Procedures and means by which manufacturing programmes and plans are determined, information issued for their execution and data collected and recorded to control manufacture in accordance with the plans.

Quality Control.

Procedures and means (including sampling methods based on statistical principles) of measuring and maintaining the quality of products.
Specialisation.

The devoting of particular productive resources exclusively to the manufacture of a narrow range of products.

Standard Costing (Chapter 20).

A system of costing in which standard costs are estimated in advance; the actual costs incurred are compared with the standards and any variance is analysed for causes.

Standardisation (Chapter 2).

The development and application of a standard for a particular product, or type of component or range of products or components or for a given procedure.

Value Analysis.

The systematised investigation of the product and its manufacture to reduce cost and improve value.

B. WORK STUDY AND TECHNICAL TERMS

† Activity Sampling (Chapter 21).

A technique in which a large number of instantaneous observations are made over a period of time of a group of machines, processes or workers. Each observation records what is happening at that instant and the percentage of observations recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs. (Activity sampling is also known as ratio-delay study; observation ratio study; snap-reading method; random observation method; and work sampling.)

See also Rated Activity Sampling.

† Analytical Estimating (Chapter 21).

A work measurement technique, being a development of estimating, whereby the time required to carry out elements of a job at a defined level of performance is estimated from knowledge and practical experience of the elements concerned.

Basic Motion Time Study (Chapter 21).

A predetermined motion time study system (q.v.).

† Basic Time (Chapter 17).

The time for carrying out an element of work at standard rating, i.e.—

\[
\text{Observed Time} \times \frac{\text{Observed Rating}}{\text{Standard Rating}}
\]

† Break Point (Chapter 15).

The instant at which one element in a work cycle ends and another begins.

† Check Time (Chapter 17).

The time intervals between the start of a time study and the start of the first element observed, and between the finish of the last element observed and the finish of the study.

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1 Chapter numbers in parentheses after a term indicate the chapter in which it is first used. Definitions marked † are identical with those used in the British Standard Glossary of Terms in Work Study, B.S. 3138, 1959.
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† Chronocyclegraph (Chapter 7).
A cyclegraph in which the light source is suitably interrupted so that the path appears as a series of pear-shaped dots, the pointed end indicating the direction of movement and the spacing indicating the speed of movement.

† Contingency Allowance (Chapter 17).
A small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays, the precise measurement of which is uneconomical because of their infrequent or irregular occurrence.

Cumulative Timing (Chapter 15).
See Timing.

† Cyclegraph (Chapter 7).
A record of a path of movement, usually traced by a continuous source of light or a photograph, preferably stereoscopic.

† Cycle Time (Chapter 18).
The total time taken to complete the elements constituting the work cycle.

† Elapsed Time (Chapter 15).
The total time from the start to the finish of a time study.

† Element (Chapter 15).
A distinct part of a specified job selected for convenience of observation, measurement and analysis.

Constant Element.
An element for which the basic time remains constant whenever it is performed.

Foreign Element.
An element observed during a study which, after analysis, is not found to be a necessary part of the job.

Governing Element.
An element occupying a longer time than that of any other element which is being performed concurrently.

Machine Element.
An element automatically performed by a power-driven machine (or process).

Manual Element.
An element performed by a worker.

Occasional Element.
An element which does not occur in every work cycle of the job, but which may occur at regular or irregular intervals.
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Repetitive Element.
An element which occurs in every work cycle of the job.

Variable Element.
An element for which the basic time varies in relation to some characteristics of the product, equipment or process, e.g. dimensions, weight, quality.

Extension (Chapter 17).
The calculation of basic time from observed time.

† Fatigue Allowance (Chapter 17).
A subdivision of the relaxation allowance intended to cater for the physiological and psychological effects of carrying out specified work under specified conditions.

† Film Analysis (Chapter 7).
The frame-by-frame examination of a ciné film of an operation to determine the state of activity of the subject during each exposure.

Fixture (Chapter 11).
A device for holding parts which would otherwise have to be held in one hand while the other worked on them.

† Flow Diagram (Chapter 7).
A diagram or model, substantially to scale, which shows the location of specific activities carried out and the routes followed by workers, materials or equipment in their execution.

† Flow Process Chart (Chapter 8).
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.

Equipment Type Flow Process Chart.
A flow process chart which records how the equipment is used.

Man Type Flow Process Chart.
A flow process chart which records what the worker does.

Material Type Flow Process Chart.
A flow process chart which records what happens to material.

Flyback Timing (Chapter 15).
See Timing.

† Idle Time (Chapter 2).
That part of attendance time when the worker has work available but does not do it.

† Ineffective Time (Chapter 2).
That portion of the elapsed time, excluding the check time, spent on any activity which is not a specified part of a job.

† Inside Work (Chapter 18).
Elements which can be performed by a worker within the machine- (or process-) controlled time.
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† Interference Allowance (Chapter 18).

An allowance of time for production unavoidably lost through synchronisation of stoppages on two or more machines (or processes) attended by one worker. Similar circumstances arise in team work.

† Interference Time (Chapter 18).

The time when the machine (or process) is idle awaiting attention, while the worker attends to another machine (or process). Similar circumstances arise in team work.

Jig (Chapter 11).

A jig holds parts in an exact position and guides the tool that works on them.

† Job Breakdown (Chapter 15).

A listing of the content of a job by elements.

† Load Factor (Chapter 18).

The proportion of the over-all cycle time required by the worker to carry out the necessary work at standard performance, during a machine- (or process-) controlled cycle.

† Machine Ancillary Time (Chapter 18).

The time when a machine is temporarily out of productive use owing to change-overs, setting, cleaning, etc.

† Machine Available Time (Chapter 18).

The time which a machine could work based on attendance time—i.e. working day or week plus overtime.

† Machine Capacity (Chapter 18).

The volume of output of a machine, usually expressed in physical units capable of being produced in any convenient unit of time, e.g. tons per week, pieces per hour, etc.

† Machine Down Time (Chapter 18).

The time during which a machine cannot be operated on production or ancillary work owing to breakdown, maintenance requirements, or for other similar reasons.

† Machine Effective Utilisation Index (Chapter 18).


† Machine Efficiency Index (Chapter 18).


† Machine Idle Time (Chapter 18).

The time during which a machine is available for production or ancillary work but is not used owing to shortage of work, materials or workers, including the time that the plant is out of balance.

† Machine Interference (Chapter 18).

The queuing of machines (or processes) for attention—e.g. when one worker is responsible for attending to more than one machine. Similar circumstances arise in team work where random delays at any point may affect the output of the team.

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† **Machine Maximum Time** *(Chapter 18).*

The maximum possible time which a machine or group of machines could work within a given period, e.g. 168 hours in one week or 24 hours in one day.

† **Machine Running Time** *(Chapter 18).*

The time during which a machine is actually operating, i.e. the Machine Available Time *less* any Machine Down Time, Machine Idle Time, or Machine Ancillary Time.

† **Machine Running Time at Standard** *(Chapter 18).*

The running time that should be incurred in producing the output if the machine is working under optimum conditions.

† **Machine Utilisation Index** *(Chapter 18).*

The ratio of: Machine Running Time
to: Machine Available Time.

† **Machine-Controlled Time** *(Chapter 18).*

The time taken to complete that part of the work cycle which is determined only by technical factors peculiar to the machine.

**Machine-Hour** *(Chapter 2).*

The running of a machine or piece of plant for one hour.

**Man-Hour** *(Chapter 2).*

The labour of one man for one hour.

† **Memomotion Photography** *(Chapter 7).*

A form of time-lapse photography which records activity by a ciné camera adapted to take pictures at longer intervals than normal. The time intervals usually lie between ¼ sec and 4 sec.

† **Method Study** *(Chapter 4).*

The systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

**Methods-Time Measurement (M.T.M.)** *(Chapter 21).*

A Predetermined Motion Time System (q.v.).

† **Micromotion Analysis** *(Chapter 7).*

The critical examination of a simo chart prepared by a frame-by-frame examination of a ciné film of an operation.

† **Multiple Activity Chart** *(Chapter 10).*

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

† **Multiple Machine Work** *(Chapter 18).*

Work which requires the worker to attend two or more machines (of similar or different kinds) running simultaneously.

**Observation Ratio Study** *(Chapter 21).*

See *Activity Sampling.*
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† Observed Time (Chapter 16).

The time taken to perform an element or combination of elements obtained by means of direct measurement.

† Outline Process Chart (Chapter 8).

A process chart giving an over-all picture by recording in sequence only the main operations and inspections.

† Outside Work (Chapter 18).

Elements which must necessarily be performed by a worker outside the machine- (or process-) controlled time.

† Personal Needs Allowance (Chapter 17).

A subdivision of the relaxation allowance intended to cater for attention to personal needs.

† Plant and Machine Control (Chapter 18).

The procedures and means by which efficiency and utilisation of units of plant and machinery are planned and checked.

Plant Layout (Chapter 9).

The production of a floor plan for arranging the desired machinery and equipment of a plant, established or contemplated, in the way which will permit the easiest flow of materials, at the lowest cost and with the minimum of handling, in processing the product from the receipt of raw material to the dispatch of the finished products.

† Policy Allowance (Chapter 17).

An increment, other than bonus increment, applied to standard time (or some constituent part of it, e.g. work content) to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstances.

† Predetermined Motion Time System (P.M.T.S.) (Chapter 21).

A work measurement technique whereby times established for basic human motions (classified according to the nature of the motion and the conditions under which it is made) are used to build up the time for a job at a defined level of performance.

P.M.T.S. Chart.

A chart or form used in recording all the movements taking place in any operation by means of one of the predetermined motion time system codes.

† Primary Questions (Chapter 8).

The first stage of the questioning technique which queries the fundamental need for the performance, place, sequence, person and means of every activity recorded, and seeks a reason for each reply.

Principles of Motion Economy (Chapter 11).

Characteristics which, when incorporated in the methods adopted, make for easier working.

† Process Charts (Chapter 7).

Charts in which a sequence of events is portrayed diagrammatically by means of a set of process chart symbols to help a person to visualise a process as a means of examining and improving it.

Process Layout (Chapter 9).

A layout in which all machines or processes of the same type are grouped together.

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† Process-Controlled Time (Chapter 18).
   The time taken to complete that part of the work cycle which is determined only by technical factors peculiar to the process.

Product Layout (Chapter 9).
   A layout in which all machines or processes concerned in the manufacture of the same product or range of products are grouped together.

† Production Study (Chapter 21).
   A continuous study of relatively lengthy duration, often extending over a period of one or more shifts, taken with the object of checking an existing or proposed standard time, or obtaining other information affecting the rate of output.

Productivity (Chapter 1).
   The ratio of output to input.

† Qualified Worker (Chapter 15).
   One who is accepted as having the necessary physical attributes, who possesses the required intelligence and education, and has acquired the necessary skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity and quality.

† Questioning Technique (Chapter 8).
   The means by which the critical examination is conducted, each activity being subjected in turn to a systematic and progressive series of questions.

Random Observation Method (Chapter 21).
   See Activity Sampling.

† Rated Activity Sampling (Chapter 21).
   An extension of activity sampling in which a rating is applied to each work element so that the work content may be established in addition to the proportion of time occupied by other activities or delays.

Rating (Chapter 16).
   (i) The assessment of the worker’s rate of working relative to the observer’s concept of the rate corresponding to standard pace.
   (ii) The numerical value or symbol used to denote the rate of working.

   (a) Loose rating: an inaccurate rating which is too high.
   (b) Tight rating: an inaccurate rating which is too low.
   (c) Inconsistent ratings: a mixture of loose, tight and accurate ratings.
   (d) Flat ratings: a set of ratings in which the observer has underestimated the variations in the worker’s rate of working.
   (e) Steep ratings: a set of ratings in which the observer has overestimated the variations in the worker’s rate of working.

† Rating Scale (Chapter 16).
   The series of numerical indices given to various rates of working. The scale is linear.

Ratio-Delay Study (Chapter 21).
   See Activity Sampling.
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† Relaxation Allowance (Chapter 17).

An addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of the allowance will depend on the nature of the job.

† Representative Worker (Chapter 16).

A worker whose skill and performance is the average of a group under consideration. He is not necessarily a qualified worker.

† Restricted Work (Chapter 18).

Work in which the output of the worker is limited by factors outside the control of the worker.

† Secondary Questions (Chapter 8).

The second stage of the questioning technique whereby 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 over the existing method.

† Simultaneous Motion Cycle Chart ("Simo Chart") (Chapter 8).

A chart often based on film analysis, used to record simultaneously on a common time scale the therbligs or groups of therbligs performed by different parts of the body of one or more workers.

Snap-Reading Method (Chapter 21).

See Activity Sampling.

† Standard Performance (Chapter 16).

The rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift provided they know and adhere to the specified method and provided they are motivated to apply themselves to their work. This performance is denoted as 100 on the standard rating and performance scales.

† Standard Time (Chapter 18).

The total time in which a job should be completed at standard performance, i.e. work content, contingency allowance for delay, unoccupied time and interference allowance, where applicable.

† String Diagram (Chapter 10).

A scale plan or model on which a thread is used to trace and measure the path of workers, materials or equipment during a specified sequence of events.

† Subtracted Time (Chapter 18).

The time taken to perform an element or combination of elements, obtained by subtracting the time recorded at one break point from that recorded at a subsequent break point, using the cumulative or differential timing method.

† Synthesis (Chapter 21).

A work measurement technique for building up the time for a job at a defined level of performance by totalling element times obtained previously from time studies on other jobs containing the elements concerned, or from synthetic data.

† Synthetic Data (Chapter 21).

Tables and formulae derived from the analysis of accumulated work measurement data, arranged in a form suitable for building up standard times, machine process times, etc., by synthesis.

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† Therblig (Chapter 11).

The name given by Frank B. Gilbreth to each of the specific divisions of movement, according to the purpose for which it is made. These therbligs cover movements or reasons for absence of movement. Each therblig has a specific colour, symbol and letter for recording purposes.

† Time Study (Chapter 14).

A work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.

† Timing (Chapter 15).

The practice of observing and recording, by the use of a watch or other device, the time taken to complete each element. Three alternative methods of timing with a stopwatch are:

Cumulative Timing.
A method in which the hands of the stopwatch are allowed to continue to move without returning them to zero at the end of each element, the time for each element being obtained subsequently by subtraction.

Differential Timing.
A method for obtaining the time of one or more small elements. Elements are timed in groups, first including and then excluding each small element, the time for each element being obtained subsequently by subtraction.

Flyback Timing.
A method in which the hands of the stopwatch are returned to zero at the end of each element and are allowed to restart immediately, the time for the element being obtained directly.

† Tool Allowance (Chapter 17).

An allowance of time, which may be included in a standard time, to cover adjustment and maintenance of tools.

† Travel Chart (Chapter 10).

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.

† Two-Handed Process Chart (Chapter 11).

A process chart in which the activities of a worker's hands (or limbs) are recorded in their relationship to one another.

† Unoccupied Time (Chapter 18).

The periods during machine- (or process-) controlled time when a worker is neither engaged on inside work nor in taking authorised rest, the time for carrying out the work being calculated at a defined performance.

† Unoccupied Time Allowance (Chapter 18).

The allowance made to a worker when there is unoccupied time during machine- or process-controlled time.

† Unrestricted Work (Chapter 18).

Work in which the output of the worker is limited only by factors within the control of the worker.
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† Work Content (Chapter 17).

Basic time + relaxation allowance + any other allowance for additional work—e.g. that part of contingency allowance which represents work.

† Work Cycle (Chapter 15).

The sequence of elements which are required to perform a job or yield a unit of production. The sequence may sometimes include occasional elements.

Work Factor (Chapter 21).

A Predetermined Motion Time System (q.v.).

† Work Measurement (Chapter 4).

The application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.

Work Sampling (Chapter 21).

See Activity Sampling.

† Work Specification (Chapter 20).

A document setting out the details of an operation or job, how it is to be performed, the layout of the workplace, particulars of machines, tools and appliances to be used, and the duties and responsibilities of the worker. The standard time or allowed time assigned to the job is normally included.

† Work Study (Chapter 4).

A generic term for those techniques, particularly Method Study and Work Measurement, which are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement.

† Workplace Layout (Chapter 11).

A convenient term used to describe the space and the arrangement of facilities and conditions provided for a worker in the performance of a specified job.
NOTES ON THE

WET KATA THERMOMETER

The wet kata thermometer is referred to in Section 13 of Chapter 17, which is concerned with relaxation allowances in hot and humid climates.

The rate at which perspiration from the human body can be dissipated depends on the ambient conditions, and specifically on:

- the temperature of the surrounding air (measurable by dry-bulb thermometer);
- the humidity (measurable by wet-bulb thermometer);
- the rate of air movement;
- the presence of hot bodies (furnaces, etc.) in the vicinity.

The effect of the first three of these factors, and thus the cooling power of the surrounding atmosphere, can be measured by the wet kata thermometer.

The thermometer is of the spirit-in-glass type, the spirit usually being coloured to facilitate reading. It can be obtained with or without a silvered bulb, the silvered type being used when it is necessary to shield the spirit from radiant heat emitted by hot bodies near to where the measurements are to be made. Kata thermometers graduated to the Fahrenheit scale are obtainable in three ranges:

<table>
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<tr>
<th>Range</th>
<th>Fahrenheit</th>
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<td>100–95° F</td>
<td></td>
</tr>
<tr>
<td>130–125</td>
<td></td>
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<tr>
<td>150–145</td>
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</table>

The 100–95° F instrument is the one usually employed for measuring environmental conditions. The instrument is about 15 cm long, with a hook and a small reservoir at the top, a stem, and the bulb at the bottom. The stem has two graduation marks only, at 100° F and 95° F. Silk net sleeves are supplied for covering the bulb of the thermometer. Each instrument is calibrated by the makers and the calibration number is etched on the stem.

Method of Use

The bulb of the thermometer must be clean and free from fingerprints. The silk net is tied round the top of the bulb, so as to shroud it, and a piece of string or wire is attached to the hook at the top so that the instrument may be suspended at the place where readings are to be made.
A small amount of hot water is required, about a cupful, at a temperature of 120–150°F (50–65°C). The bulb, shrouded in its net, is immersed in the hot water until the spirit climbs about halfway up the stem, well above the top mark. The thermometer is then removed from the hot water and excess water is removed from the net by squeezing bulb and net lightly in a clean dry rag.

The thermometer is then suspended at the place where readings are required. Care must be taken not to disturb the normal flow of air at the place being investigated, and the thermometer must hang without swinging. A stopwatch is used to determine the time taken for the liquid level to fall from the upper to the lower graduation mark. It may be necessary to ignore the first few readings, after which a minimum of five readings should be taken. These may exhibit fairly wide variations in time as the instrument is susceptible to variations in the air flow.

The average time is converted into seconds (if a decimal minute stopwatch has been used) and the cooling power of the atmosphere is determined by dividing the thermometer constant by the average time. For instance, if the thermometer constant is 459 and the average time recorded 85 seconds, the cooling power—the ability of the atmosphere to absorb additional moisture—would be 5.40 milli-calories per square centimetre per second.

Tentative relaxation allowances at selected kata readings are shown in table 13 on page 300.

It is usually of interest to record wet-bulb and dry-bulb temperatures at the same time as kata readings because these temperatures are more widely understood than kata recordings, but it must be remembered that wet- and dry-bulb temperatures do not take into account any air movement, which can make a great difference to comfort in hot, humid conditions.
A CHECK-LIST OF QUESTIONS

WHICH MAY BE OF USE IN APPLYING

THE QUESTIONING SEQUENCE

IN METHOD STUDY

Most of the questions listed below apply generally to method study investigations. They amplify the questioning procedure described in Chapter 8, and may be of service in suggesting to studymen aspects of the method which might otherwise be overlooked. The questions are listed under the following headings:

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<th>Material</th>
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<td>Inspection Requirements</td>
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<tr>
<td>Process Analysis</td>
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</tr>
</tbody>
</table>

**Operations**

1. What is the purpose of the operation?
2. Is the result obtained by the operation necessary?
   If so, what makes it necessary?
3. Is the operation necessary because the previous operation was not performed correctly?
4. Is the operation instituted to correct a condition that has now been corrected otherwise?
5. If the operation is being carried out to improve appearance, does the additional cost give extra saleability?
6. Can the purpose of the operation be obtained in another way?
7. Can the material supplier perform the operation more economically?
8. Is the operation being performed to satisfy the requirements of all users of the product, or is it made necessary by the requirements of one or two customers only?
9. Does a subsequent operation eliminate the necessity for this operation?
10. Is the operation being performed as a result of habit?
11. Was the operation established to reduce the cost of a previous operation, or a subsequent operation?
12. Was the operation added by the sales department as a special feature?
13. Can the part be purchased at a lower cost?
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14. Would adding a further operation make other operations easier to perform?
15. Is there another way to perform the operation and still maintain the same results?
16. If the operation has been established to correct a subsequent difficulty, is it possible that the corrective operation is more costly than the difficulty itself?
17. Have conditions changed since the operation was added to the process?

Design

1. Can the design be changed to simplify or eliminate the operation?
2. Is the design of the part suitable for good manufacturing practice?
3. Can equivalent results be obtained by changing the design and thus reducing cost?
4. Can a standard part be substituted?
5. Would a change in design mean increased saleability, an increased market?
6. Can a standard part be converted to do the job?
7. Is it possible to improve the appearance of the article without interfering with its utility?
8. Would an additional cost caused by improved appearance and greater utility be offset by increased business?
9. Has the article the best possible appearance and utility on the market at the price?

· Inspection Requirements

1. What are the inspection requirements for this operation?
2. Does everybody involved know exactly what the requirements are?
3. What are the inspection details of the previous and following operations?
4. Will changing the requirements of this operation make it easier to perform?
5. Will changing the requirements of the previous operation make this operation easier?
6. Are tolerance, allowance, finish and other standards really necessary?
7. Can standards be raised to improve quality without unnecessary cost?
8. Will lowering standards reduce cost considerably?
9. Can the finished quality of the product be improved in any way above the present standard?
10. How do standards for this operation/product compare with standards for similar items?
11. Can the quality be improved by using new processes?
12. Are the same standards necessary for all customers?
13. Will a change in standards and inspection requirements increase or decrease the defective work and expense in the operation, shop or field?
14. Are the tolerances used in actual practice the same as those used on the drawing?
15. Has an agreement been reached by all concerned as to what constitutes acceptable quality?
16. What are the main causes of rejections for this part?
17. Is the quality standard definitely fixed, or is it a matter of individual judgment?

Materials Handling

1. Is the time spent in bringing material to the work station and in removing it large in proportion to the time used to handle it at the work station?
Appendix 7

2. If not, could material handling be done by the operators to provide a rest through change of occupation?
3. Should hand, electric or fork-lift trucks be used?
4. Should special racks, containers or pallets be designed to permit the handling of material with ease and without damage?
5. Where should incoming and outgoing materials be located in the work area?
6. Is a conveyor justified, and if so, what type would best be suited for the job?
7. Can the work stations for progressive steps of the operation be moved closer together and the material handling problem overcome by gravity chutes?
8. Can material be pushed from operator to operator along the bench?
9. Can material be dispatched from a central point by means of a conveyor?
10. Is the size of the container suitable for the amount of material transported?
11. Can material be brought to a central inspection point by means of a conveyor?
12. Can a container be designed to make material more accessible?
13. Could a container be placed at the work station without removing the material?
14. Can an electric or air hoist or any other lifting device be used with advantage?
15. If an overhead travelling crane is used, is the service prompt and accurate?
16. Can a tractor-trailer train be used? Could this or an industrial railway replace a conveyor?
17. Can gravity be utilised by starting the first operation at a higher level?
18. Can chutes be used to catch material and convey it to containers?
19. Would flow process charts assist in solving the flow and handling problem?
20. Is the store efficiently located?
21. Are truck loading and unloading stations located centrally?
22. Can conveyors be used for floor-to-floor transportation?
23. Can waist-high portable material containers be used at the work stations?
24. Can a finished part be easily disposed of?
25. Would a turntable eliminate walking?
26. Can incoming raw material be delivered at the first work station to save double handling?
27. Could operations be combined at one work station to save double handling?
28. Would a container of standard size eliminate weighing?
29. Would a hydraulic lift eliminate a crane service?
30. Could the operator deliver parts to the next work station when he disposes of them?
31. Are containers uniform to permit stacking and eliminate excessive use of floor space?
32. Could material be bought in a more convenient size for handling?
33. Would signals, i.e. lights, bells, etc., notifying men that more material is required, save delay?
34. Would better scheduling eliminate bottlenecks?
35. Would better planning eliminate crane bottlenecks?
36. Can the location of stores and stockpiles be altered to reduce handling and transportation?

Process Analysis

1. Can the operation being analysed be combined with another operation? Can it be eliminated?
Appendix 7

2. Can it be broken up and the various parts of the operation added to other operations?
3. Can a part of the operation being performed be completed more effectively as a separate operation?
4. Is the sequence of operations the best possible, or would changing the sequence improve the operation?
5. Could the operation be done in another department to save the cost of handling?
6. Should a concise study of the operation be made by means of a flow process chart?
7. If the operation is changed, what effect will it have on the other operations? on the finished product?
8. If a different method of producing the part can be used, will it justify all the work and activity involved?
9. Can the operation and inspection be combined?
10. Is the job inspected at its most critical point, or when it is completed?
11. Will a patrol form of inspection eliminate waste, scrap and expense?

Material
1. Is the material being used really suitable for the job?
2. Could a less expensive material be substituted and still do the job?
3. Could a lighter-gauge material be used?
4. Is the material purchased in a condition suitable for use?
5. Could the supplier perform additional work on the material that would improve usage and decrease waste?
6. Is the material sufficiently clean?
7. Is the material bought in amounts and sizes that give the greatest utilisation and limit scrap, odd cuts and short ends?
8. Is the material used to the best possible advantage during cutting, processing?
9. Are materials used in connection with the process—oils, water, acids, paint, gas, compressed air, electricity—suitable, and is their use controlled and economised?
10. How does the cost of material compare with the cost of labour?
11. Can the design be changed to eliminate excessive loss and scrap material?
12. Can the number of materials used be reduced by standardisation?
13. Could the part be made from scrap material?
14. Can newly developed materials—plastics, hardboard, etc.—be used?
15. Is the supplier of the material performing operations on it which are not necessary for the process?
16. Can extruded materials be used?
17. If the material was of a more consistent grade, could better control of the process be established?
18. Can a fabricated part be substituted instead of a casting to save pattern costs?
19. Is the activity low enough to warrant this?
20. Is the material free from sharp edges and burrs?
21. What effect does storage have on material?
22. Could a more careful inspection of incoming materials decrease difficulties now being encountered in the shop?
Appendix 7

Workplace Layout

1. How is the job assigned to the operator?
2. Are things so well controlled that the operator is never without a job to do?
3. How is the operator given instructions?
4. How is material obtained?
5. How are drawings and tools issued?
6. Is there a control on time? If so, how are the starting and finishing times of the job checked?
7. Are there many possibilities for delays at the drawing room, tool room, storeroom and at the clerk's office?
8. Does the layout of the work area prove effective, and can it be improved?
9. Is the material properly positioned?
10. If the operation is being performed continually, how much time is wasted at the start and end of the shift by preliminary operations and cleaning up?
11. Are tools prepositioned to save mental delay?
12. How is material supply replenished?
13. Can a hand or foot air jet be supplied to the operator and applied with advantage?
14. Could jigs be used?
15. Could guides or bullet-nosed pins be used to position the part?
16. What must be done to complete the operation and put away all the equipment?
17. How thoroughly should the workplace be cleaned?

Tools and Equipment

1. Can a jig be designed that can be used for more than one job?
2. Is the volume sufficient to justify highly developed specialised tools and fixtures?
3. Can a magazine feed be used?
4. Could the jig be made of lighter material, or so designed with economy of material to allow easier handling?
5. Are there other fixtures available that can be adapted to this job?
6. Is the design of the jig correct?
7. Would lower-cost tooling decrease quality?
8. Is the jig designed to allow maximum motion economy?
9. Can the part be quickly inserted and removed from the jig?
10. Would a quick-acting, cam-actuated mechanism be desirable for tightening the jig, clamp or vice?
11. Can ejectors be installed on the fixture for automatically removing the part when the fixture is opened?
12. Are all operators provided with the same tools?
13. If accurate work is necessary, are proper gauges and other measuring instruments provided?
14. Is the wooden equipment in use in good condition and are workbenches free from splinters?
15. Would a special bench or desk designed to eliminate stooping, bending and reaching reduce fatigue?
Appendix 7

Working Conditions

1. Is the light even and sufficient at all times?
2. Has glare been eliminated from the workplace?
3. Is the proper temperature for comfort provided at all times; if not, can fans or heaters be used?
4. Would installation of air-conditioning equipment be justified?
5. Can fumes, smoke and dirt be removed by exhaust systems?
6. If concrete floors are used, is sacking or matting provided to make standing more comfortable?
7. Are drinking fountains with cool water provided and are they located nearby?
8. Has due consideration been given to safety factors?
9. Is the floor safe, smooth but not slippery?
10. Has the operator been taught to work safely?
11. Is the clothing suitable from a safety standpoint?
12. Does the plant present a neat and orderly appearance at all times?
13. How is the amount of finished material counted?
14. Is there a definite check between pieces recorded and pieces paid for?
15. Can automatic counters be used?
16. What clerical work is required from operators for filling in time cards, material requisitions and the like?
17. How is defective work handled?
18. What is the economic lot size for the job being analysed?
19. Are adequate records kept on the performance of operators?
20. Are new employees properly introduced to their surroundings and do they receive sufficient instruction?
21. When workers do not reach a standard of performance are the details investigated?
22. Are suggestions from workers encouraged?
23. Do the workers really understand the incentive plan under which they work?
24. Is a real interest developed amongst the workers on the product?
25. Is the operation being performed by the proper class of labour?
26. Is the operator physically suited for the job?
27. Is the plant unduly cold in winter, or stuffy in summer, especially on the first morning of the week?
BOOK LIST

WORK STUDY AND ITS USES


Appendix 8


**INTERFERENCE IN MULTI-MACHINE OPERATION**

**AND OUTPUT CALCULATIONS FOR MULTI-MACHINE WORK**

Idem: "A Table for Predicting the Production from a Group of Machines under the Care of One Operative", in ibid., 1954, 16B, pp. 285-287.


Idem: "A Table for Predicting the Production from a Group of Machines under the Care of One Operative", in ibid., 1954, 16B, pp. 285-287.


**PREDETERMINED MOTION TIME SYSTEMS**


Appendix 8


WORK STUDY IN THE OFFICE


VALUE ANALYSIS


INDUSTRIAL MANAGEMENT AND PRODUCTIVITY


INCENTIVES


Appendix 8


THE WET KATA THERMOMETER


