Time and Motion Study in Chemical Industry

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Definitions :—

TIME study is the accurate analysis of the time necessary to perform an operation or part thereof. The operation may be simple or complex. In the latter case it is to be divided into constituent simple operations, and the time taken for each such operation separately determined. Further, the time taken by a representative worker to perform these operations under a given set of conditions, is studied in detail.

Motion study is a science of eliminating wastefulness arising from using unnecessary and inefficient motions in the performance of an operation. Motion study results in the linking of various essential motions in the most economical sequence.

Aim :—

The main aim of time and motion study is to reduce fatigue by introducing rhythm into the movements, to reduce wasted efforts and to establish the optimum time required for a given operation. Time and motion study usually results in shorter time for completing the specific job, not by overspeeding the worker, but by determining the best conditions under which the work can be carried out. This might necessiate installation of new machines, equipment and the like, with a view to secure better results .

Application to Chemical Industry :—

In the case of mass production industry, where identical motion cycles are repeated number of times by a group of workers. Systematic investigations of motion economy have been successfully carried out. Operations involved in chemical industry are too varying in scope, sequence and charge and as such the applicability of time and motion study may not be immediately apparent. However, there is ample scope for applying these study methods, not only to the chemical industry, but even to the chemical laboratory. Hence it will be in the interest of all chemists and chemical technologists to know more about this fascinating but much misunderstood subject.

Selection of a person :—

Selection of the person for time and motion study is a very important factor, for obtaining truely representative data. No person, however skilled, uses the best motions throughout. One person may be using a most effective motion for some part of the operation, while another person for another part. The best of each person's motion sequence is taken and the various movements fitted together to form a new sequence. This makes it possible to carry out the work in minimum time, with minimum effort. Together with the most rapid worker, the laziest worker should also be selected as he usually develops ingeneous shortcuts and the most direct and economical movements.

Measurement of time :—

In the earlier investigations, a stop watch was used as a time measurer. For measuring time, a major operation is first divided into elementary operations. Shorter time for elementary operation gives more accurate results and more accurate description of an elementary operation. In searching or inspecting, for example, movement of the eyeball up or

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down takes 10 per cent less time than the movement of the head in the same angle. For sidewise, the recorded time is about equal (but movements of the eyeball consumes less energy).

Mass timing of large groups of elementary operations, though justifiable as a check, is useless as far as scientific analysis or improvement in the method is concerned. Each successive operation can be timed separately to improve one elementary operation, but it disturbs automacity of the work and the delay-times are lost. To have close timing, each one of the elementary operations is separately timed during successive cycles. By this procedure, it is not possible to check the over-all time consumed by the operation. In both the methods, errors of starting and stopping the stop-watch, affects the accuracy of the results. The best method is to record elementary operations in sequence without stopping the watch. Time is recorded with sufficient speed and concentration as soon as each elementary operation is completed. This method gives exact time for each elementary operation and cumulative time for all. Every minute of time for duration of study is charged either to some necessary or productive elementary operation or to unnecessary or non-productive elementary operation.

Delays :—

The study also brings out, whether there are avoidable or unavoidable delays during the given operation. Avoidable delays can be overcome and eliminated by taking some definite means whereas unavoidable delays are due to necessary motions occurring irregularly during the performance of a job (e.g. removing of finished products from the machine, receiving instructions etc.). It is very important to bear in mind that these delays are not accounted for in short studies and hence studies must extend over a long period to arrive at a standard.

There are some delays inherent in the very nature of the operation, e.g. time needed for the reaction to take place, time needed for evaporation, crystallization, drying etc. Some delays are caused by the others such as in getting material, chemicals, equipment etc. In some cases, i.e. semidelays—attention of the operator is required, but still he can carry out the other work. Examples of such type of delays are ordinary distillation, heating and cooling operations, filtration, etc. Such type of delays can be overcome by planning optional work to fill entirely all the delays. 2-3 minutes semidelays can be profitably utilized in reading, as attention is usually high during such brief periods. Conscious and complete relaxation during such periods helps to overcome fatigue.

Much time can be saved in a chemical works by proper planning of the day's work. This planning can be divided into macroplanning i.e., work to be done during the whole day and micro-planning, for small requirements of work (e.g. titrations, weighing of chemicals etc.) which may require fraction of an hour.

Micromotion procedure :—

Stopwatch method cannot record finer portions of high dexterity and hence micromotion techniques are used. There are two photographic techniques, one using a still picture camera with series of superimposed motion paths on one plate and the other using a motion picture camera with a series of separate pictures.

All these experiments should be preferably carried out in a special room, since it is less embarassing to the person if the pictures are taken away from his regular work place. Incidentally, as the fear of audience is removed, high degree of cooperation can be brough about. The person should be instructed to work at normal rate.

Cyclegraph method :—

In one method, a small electric light, known as cyclegraph, is attached to the tool or limb of a person whose motion is to be studied. Path of movement is indicated by a continuous line on a photographic film. Timing is obtained by including an interrupter of known period in the electric lamp circuit. Slow and fast movements are thus made visible by short and long dashes. By arranging that with each illumination of the lamp, the incandescence of filament shall be completed quickly and die away slowly, the dashes will appear broadest at the earlier end, tailing off to a point at their later end, thus representing arrowheads and indicating sense of motion. Finally, absolute direction in space of each motion is studied by stereoscopically photographing the movement. A wire model giving a path of motion in three dimensions can be constructed from such photograph. This model can be examined from any angle, as against a photograph which represents a path of movement only from the angle at which it was originally taken.

Photographic method :—

In another method motions of the person are photographed on the film. Timing is obtained by a micro-chronometer placed within the picture range. The projector, while projecting the film may be stopped at any instant or may be slowly reversed to note the clock-reading at the beginning and the end of each elementary operation.

Advantages :—

Above stated micromotion procedures have several advantages over stopwatch procedures. They record all conditions, except sound, which affect work. Time and motion are recorded automatically, and more accurately and human factor is reduced to minimum. Method or study of motion is given a primary consideration, time being a by-product. Records provide permanent basis for accurate comparison and study. Micromotion studies can be made at equal or less cost than stop-watch studies.

Basic Rules :—

Based on time and motion study, following basic rules particularly applicable to work of chemist and chemical technologist may be formulated.

1. There are many good ways of doing a thing but one way is the best under a given set of circumstances. (Even the best way of doing things may be bettered if circumstances are altered).

2. The best way of doing anything is almost always the sequence of the least number of elementary operations.

3. Movements should be of such type as to cause a minimum of fatigue.

4. Acquiring correct habits is more important than either efficiency of an operation or quality of product. While training a new operator, he should be immediately trained, in the manner of an expert, disregarding the quality of the output. Usually emphasis is placed on correct habits rather than speed as such, but it must be remembered that if a person learns a path of slow motion, he can never acquire a good speed unless he unlearns his entire previous training.

5. The 'do' portion of the work should be mechanised to the extent it is economically possible. It is a false economy, for example, to stir with hand when within the same time or even less time a mechanical stirrer could be set to do it.

6. Transport distance should be made as small as possible. Here the term 'transport' includes bodily movements of a person in the factory as also the movement of a conical flask from the

table to a reagent bottle, few inches apart. A greater part of the actual mileage covered in the laboratory in the course of day's work could be avoided by proper planning of the trips to balance room, library, stores and other departments. Materials should be placed at an appropriate distance to reduce motion needed for grasping them.

7. Work should be so arranged that forearm pivots about the elbow and the need for lifting the elbow elinminated. This can be easily done by providing a bench or stool of suitable height.

8. Wherever possible, colour system should be utilized to minimise search time. Bottles containing acids, alkalies, hydrocarbons, esters, etc. should be provided with different coloured labels and they should be arranged in a definite order.

9. Hesitation must be analyzed, explained and eliminated. The average chemist when in need of a material available at his working place, hesitates 1.5 seconds before he actually locates it. If this is repeated ten times per hour or hundered times per day, 14 hours per year per chemist are lost on this item alone. Other similar items together will add up to a large figure.

10. When a constant is determined directly or from the literature, it should be written on the label of the chemical in question to avoid loss of time in locating it again from the books or records.

11. All muscles, not currently in use, should be relaxed. To conserve energy-work which can be done in a sitting position should not be done standing. In any case, working place must be provided with sufficient number of stools. Frequently, time is saved by periodic rest pauses. In extensive and continuous work like reading, it is advisable to pause five minutes every hour for complete relaxation.

12. Use of proper equipment for the specific purpose is also very important. Sometimes equipment for setting parallel work is not available, resulting in waste of time. Cost of few more thermometers, beakers, flasks etc. and breakage is definately less than the value of time saved.

Examples :—

The fact that much energy and time can be saved by the application of time and motion-study is evident from the following example. When pipetting out a liquid, say 25 c.c. from a 50 c.c. beaker, there is always a sidewise motion of the head to ascertain the distance from the top of the pipette to the surface of the liquid. Besides, there is a constant fear of getting air into the pipette or liquid into the mouth. This hesitation leads to waste of time. Motion economy of the work in view and time saving can be effected by having a mirror placed so that a glance at it will show the side view of the liquid level and tip of the pipette.

When best job sequence and equipment have been determined upon, best arrangement of machines, work benches and reserve spaces should be studied. If fatigue is to be avoided, laboratory stools should be high enough to bring the work level with the elbow of the chemist, when his arms are hanging straight down. This reduces muscular effort in lifting the lower part of the arm for almost every move. These needless motions, add up to a very large figure in the course of a day's work. Concrete or hard floor causes muscular fatigue which results in loss of efficiency. Hence floor should be covered, at least near the work benches with resilient material.

In highly mechanised work rearrangement should follow sequence of operations to avoid all unnecessary movements regardless of appearance. This study may develop desirable alterations in building or interdepartmental conveying practice.

Application :—

Once the plans for the best, easiest and most direct motion are fixed, the next step for the motion-study man is to test these himself. He should try various ways of doing the job, measuring his success by the time spent and output obtained. After devicing a series of motions that are definitely faster and less fatiguing than those in use, they should be taught to the person by motion-study man himself or through the trainer. Beginners are able to learn without great difficulty whereas in case of older workers, where habits and methods have become set, a little more effort is required.

One of the most striking development of the modern management is the application of highest intelligence to the guidance of the worker of the lowest intellect. There are strong reasons to believe that skill can be communicated or assisted by instructions. These instructions need not necessarily be from the expert but they can be from a person who has acquired the knowledge from an expert. Such a person is equally well suited to transmit the knowledge to one not aware of it.

Rate determination :—

Time study methods can be conveniently used for fixing the rates. Time taken for a particular operation is considered in three sections. (a) the time taken in reading the instructions and handling the tools. (b) The time taken in setting the equipment. (c) Time for actual operation when running.

The time for the first two operations is taken in minutes. There are various methods for determining the time for actual operation.

Standard Formulæ :—

One method uses the standard empirical formulæ. For using these formulæ, elementary operations are divided into smallest parts which can be recorded by a stopwatch. Surrounding conditions under which the work is carried out is also described as accurately as possible. These empirical formulæ can be used where detailed study of the operation is relatively expensive.

Usually, the time actually needed to perform various operations without any delays are recorded. In actual practice, it has been noticed that there is a difference betwen the work a man can do for short streches and what he can maintain over long periods. For the average worker, there is a variation of 40% between the daily production and rate at times during the same day. Before standardizing a specific performence, allowance should be made for various delays.

Allowances :—

Allowances have been standardized by merrick under five heads : Fatigue, variation in rhythm, unavoidable delays, personal delays and machine delays. From thousands of careful studies, Merrick derived the following mathematical relationship between percentage allowance (P), percentage handling time (C) and minimum selected time for cycles in minutes (T)

$$P = 20 + \frac{49 \cdot 5 - 0 \cdot 325C}{\sqrt{0 \cdot 376 - 0 \cdot 0000216C^2 + T}}$$

Other unavoidable delays are accounted for by addition of arbitary allowances e.g. 25% on preparation time. These allowances are of particular importance in the case of automatic processes. Allowances for personal needs, rest and washing up are derived from studies extending over relatively long periods. Allowances for necessities of time and fatigue range from 2.5 to 33 1/3% and 5 to 100% respectively.

When machinery is properly maintained to run as closely as possible at pre-

determined speed following allowances are made :—

Power driven, power fed—5%
Power driven, hand fed—20%
Power driven, sensitive hand fed—25%

Even though good operator on any job can exceed task by 10 to 15%, such task cannot to considered as being too liberal.

Importance :—

Costs of operating time study are usually included in the plant operating charges, but sometimes they may be made directly against the department receiving the service. In a large factory, one or more persons are engaged in the time-study section. The true cost of time study is not the labour but efficiency and satisfaction with which production and service labour works. The test of success of the first studyman is whether he has increased the speed and quantity of output and has reduced the strain of work. If either of the two results is not achieved work must be judged unsatisfactory and incomplete.

If conditions of production are not changed then there is no need to revise the conclusions based on time and motion study, though on occasional check-up, particularly with regard to climatic variations, may be desirable. On the other hand, if changes in the method of production, materials or machines are made a revision becomes necessary, based on which new schedule can be drawn up.

Employer's objection :—

Even though, there are several advantages in the time and motion study system, it has been strongly criticised, both by the employers as well as the workers. The excessive initial cost involved in conducting the time and motion study is the main objection, but reduction of total cost does not mean reduction in the unit cost of production.

The second objection is that a sudden introduction of such a system may dislocate existing management of work, resulting in decreased production and higher initial cost. This can be avoided by introducing the scheme in stages.

Management also objects to the addition of overhead charges on the ground that it is not possible to bear them during the period of depression. This difficulty can be overcome by building a fund from the substantial profits earned by the management by the introduction of this system. Thus the situation created by depression can be met with.

Employee's objection :—

The average worker feels that this method of measuring his rate of work is an insult to his personal dignity. He further thinks that the primary and the only purpose is "speeding-up" and that acceptance of the new method will reduce his status as a human being. Actually a worker should take greater and intelligent interest in his work as he is intimately associated with a group of instructors who demonstrate to him the best method of performing the job. Workers further complain that introduction of time and motion study invariably leads to discharge of workers who are not always found alternate employment. In the interest of good employer and employee relations, it is upto both to take a realastic view of the situation. Thus employer should create alternate employment for eredundant worker who in turn should be prepared to take up a new job.

Limitations of the data :—

Sometimes dissatisfaction arises from the way in which the method has been introduced or from lack of good faith on the part of the management or workers whose work has been studied. Many times it is observed that the set conditions under which the tests were made

are not reproduced in day -to-day practice. At the time when study is carried out, actual condition of material, tool, equipment, lighting, ventilation, temperature etc. are stated. As far as possible management should try to maintain these conditions. Workers should be given some compensation if at any time the optimum conditions cannot be maintained. Once the method is properly understood by the worker, they will demand for its extension.

Conclusion :—

The value of time and motion study is revealed by the fact that it provides the opportunity for critical study of elementary operations, eliminates unnecessary movements and delays, gives the best way of doing every job and helps in rate-setting of the job. However, the motion study concerns with human being and as such it is not completely an impersonal, though rational, branch of science. It should be rightly classified as " philosophy " where both psychology and science have to be considered together. Pioneers in this study have written that ' time is money '. However this is only a part of the truth. Time constitutes the life everybody has got at his disposal and even a second, once passed and wasted cannot be brought back at any cost. Time cannot be evaluated.

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