Productivity
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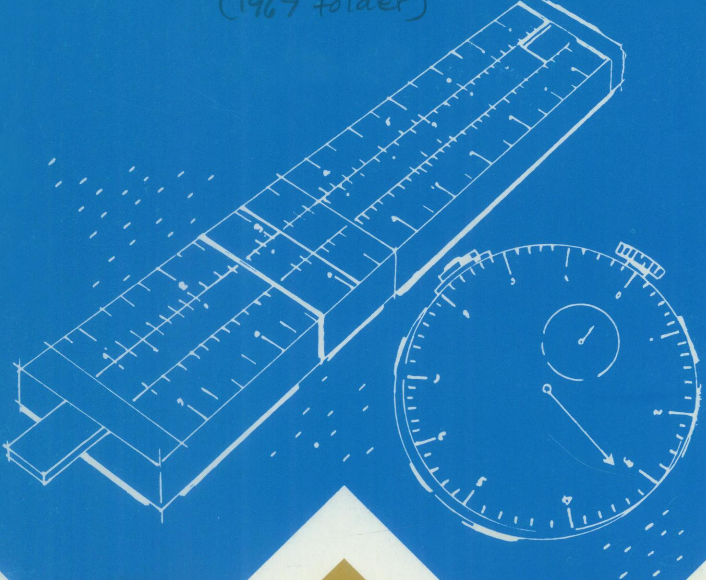

[International Union, Allied Industrial Workers of America (AFL-CIO)]

WORK MEASUREMENT

INTERNATIONAL UNION ALLIED INDUSTRIAL WORKERS OF AMERICA
AIW

WORK MEASUREMENT

A GUIDE FOR LOCAL UNION BARGAINING COMMITTEES AND STEWARDS

INTERNATIONAL UNION, ALLIED INDUSTRIAL WORKERS
OF AMERICA, (AFL-CIO)

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I . . . FOREWORD

According to a survey conducted by the U. S. Labor Department, slightly more than one out of every four workers employed in manufacturing industry were covered by some type of work measurement system and wage incentive plan in 1958. This might lead one to conclude that collective bargaining problems and grievance handling problems associated with work load and incentive disputes occupy no more than a proportionate amount of the energies of union representatives.

However, this is not the case. Disputes revolving around this issue consume a disproportionate share of the time spent by union representatives in resolving grievances. In shops where a work measurement system and/or a wage incentive plan are in effect it isn't unusual for seventy-five percent of the grievances to evolve out of the application and interpretation of these measures.

If use of industrial engineering techniques and wage payment plans related to production standards was of recent origin, the excess of disputes in this area might be easier to understand. It is only natural that there must be a "shake down" cruise when a new technique is developed before there can be smooth sailing. But this is not the case. As will shortly be pointed out, the practices and principles involved have been utilized by various segments of industry for many years.

Actually, there are many instances where the grievance ratio goes up as the system matures. In some cases this comes about because the company involved deliberately established "loose" rates at the time of the inception of the plan in order to gain worker acceptance. Then, after the plan has been in effect long enough to become well established, the industrial engineering department is instructed to tighten rates. The end result is controversy and conflict of such magnitude that work load disputes completely dominate grievance machinery.

We also find that many companies are inviting trouble by insisting that the only way they can remain competitive is through tightening existing rates or introduction of a formal work measurement system where none existed before.

Very frequently investigation reveals that these are inefficient companies which are functioning in antiquated structures and utilizing obsolete production equipment and procedures. They are trying to compete in a 20th century economy using 19th century facilities.

These companies are misguided when they think that they can survive by introducing or tightening work standards. They are only deferring the day of reckoning. Tightened work standards may provide temporary relief but they do not offer a permanent respite. Even the prospects for reduced production costs by means of the anticipated reduction in direct labor costs may not materialize. At least some evidence exists to the effect that the cost of installing and maintaining production standards exceeds the gains.

Whatever the end result may be from management's point of view there is clear evidence of considerable difficulty in the area of work load disputes and incentive wage payments. Unfortunately, in some cases, unions are not equipped to cope with and/or resist management's persistent and seemingly tireless efforts in this respect. Even where there are trained time study stewards who devote full time to work load disputes the union is likely to be outnumbered on the order of 6 or 7 to one. Management's industrial engineering departments are often densely populated.

Then, too, industrial engineers tend to be a little disdainful in their attitude toward union time study stewards apparently because the latter are considered "unschooled" by the former. This is a highly presumptuous and totally unjustified attitude but, nevertheless, it does persist and it does impede settlement of work load disputes.

The simple solution to the myriad problems arising in this area is elimination of industrial engineering approaches to determination of work load and incentive pay plans in favor of negotiated work loads and wage rates. This is exactly what has been done in a number of cases. However, in plants where this is neither possible nor probable, the alternative is to learn how to deal with the problem.

II . . . HISTORICAL BACKGROUND

Management's use of industrial engineering methods to determine work load is not of recent origin. Actually, the seeds of present day techniques were sown over three-quarters of a century ago.

It is generally agreed that work measurement was originated back in 1881 in the machine shop of the Midvale Steel Company by Frederick W. Taylor. Taylor evolved the idea that "rule-of-thumb" judgments with respect to work load could be eliminated in favor of a more "scientific" system based on stop watch time studies.

Among Taylor's accomplishments is the example of work he did while employed in the Bethlehem Steel Works. Some 400 to 600 men were assigned the task of shoveling various types of material stored in a yard approximately 2 miles long by a quarter of a mile wide.

Upon investigation Taylor found that the men were handling loads ranging from 3½ pounds, in the case of rice coal, to 38 pounds in the case of iron ore. Taylor set two observers to work with stop watches observing the performance of men handling various sizes of shovels and varying weights of material.

Through this process he discovered that the optimum load which a man could handle, in terms of total tonnage handled in a day, was 21½ pounds. Shovels were furnished which could hold a 21½ pound load of the type of material being handled, be it rice coal or iron ore. Work assignments were made for the entire day as the men reported for work.

Instead of working in groups as had been the practice in the past, the men worked independently. The material handled by each man was weighed separately and those who met the work task were paid a 60% bonus above their daily wages. Eventually, 140 men were doing the same amount of work formerly done by 400 to 600 men.

Taylor's records also refer to an instance in which pig iron workers were induced to increase production by 400% in return for a 40% increase in earnings.

In this connection Taylor wrote:

"Now one of the very first requirements for a man who is fit to handle pig iron as a regular occupation is that he shall be so stupid and so phlegmatic that he more nearly resembles the mental make-up of the ox than any other type."[1]

In the face of demeaning pronouncements such as this and a growing suspicion that Taylor had little interest in the welfare of workers and even less understanding, unionists of the time rebelled.

Opposition to Taylor's methods and the numerous variations developed by his followers finally reached such a peak that Professor Robert F. Hoxie of the University of Chicago was appointed by the U. S. Commission on Industrial Relations to study developments in the field with a view to

1. F. W. Taylor, The Principles of Scientific Management, Harper and Brothers, New York, 1911, p. 59.

discovering whether the "scientific" management movement and the labor movement could reconcile their views.

The results of Hoxie's study were published in 1915 under the title "Scientific Management and Labor."[1] In essence he found that to a considerable degree the fears of workers were well founded. Rather than eliminating judgment from the act of ascertaining a fair day's work, Hoxie found that Taylor's methods merely substituted the judgment of the time study man for that of foremen and workers.

Today, in addition to setting standards by means of the stopwatch techniques originated by Taylor, the industrial engineer is using variations such as standard data, predetermined motion time systems and work sampling. However, the stopwatch still remains a major factor in setting standards. It can also be said that the principles which underlie stopwatch studies are embodied in virtually every form of work measurement.

Consequently, while this booklet will cover all major forms of work measurement in current use, major emphasis will be placed on the factors and issues involved in establishing standards by means of stopwatch time studies.

1. R. F. Hoxie, Scientific Management and Labor, D. Appleton and Co., New York, 1915.

III . . . A SYSTEM BASED ON JUDGMENT

Work measurement has been applied to virtually every kind of work. In some cases measurement is formalized and systematized. In other cases measurement is quite informal, involving only the vaguest indication that acceptable performance includes quantitative as well as qualitative goals.

This fact deserves emphasis because many workers, in the absence of a formalized work measurement system, are inclined to forget that, in spite of this fact, they too are subject to work measurement. No employer permits his employees to select their own work pace and work load. In one way or another, directly, formally or informally, employers convey their views to employees.

In a good many cases it is the foreman who, having held a production job, decides how much should be produced based on his own past experience. In other cases historical factors govern and in still others process requirements set the pace.

If it is true that work load determination is present in most jobs, it is equally true that resolution of this issue involves almost inevitable conflict between workers and employers. Dr. William Gomberg, former head of the International Ladies Garment Workers Union's industrial engineering division, illuminated this problem very effectively when he called attention to the fact that employers have an intensive interest in production while workers have an extensive interest.

He pointed to the obvious fact that a company which wishes to be profitable and competitive has a natural interest in maximizing output per unit of input. In a given period of time, such as an hour, day or week, the more product an employer gets from his investment in capital and labor, the more profitable his enterprise will be.

On the other hand, workers have an equally vital interest in being able to work, not just for a day, hour or week, but for an entire lifetime. It does a worker no good to be able to produce at a high level for brief periods. He must, in his own best interest, produce at a pace which he can sustain for his working lifetime.

Herein lies the crux of the matter. There is no "scientific" means of resolving this natural and inevitable difference between the interests of employers and the interests of workers. To make matters worse there is no single answer. While some industrial engineers speak fondly of a universal concept of "normal" performance and most predetermined motion time systems accept this as an established fact, those who hold this view are dwelling in illusions.

This is why many trade unionists feel that a collective bargaining solution to work load determination is realistic and practical. The combined judgment of experienced negotiators will, for the most part, yield as valid and as reliable an end result as the most sophisticated system available to the industrial engineer.

No doubt this will strike many readers as a rather extreme statement. How could such a crude tool as collective bargaining yield results which compare, in terms of validity and reliability, with the results an industrial engineer gets from any work measurement system?

The answer is to be found in analysis of the techniques employed by industrial engineers in establishing production standards.

When a time study man sets out to establish work standards, he assumes responsibility for determining the time it *should* take a *qualified worker* performing at a *normal pace* to perform a specific task according to a *predetermined method* and under *certain conditions.*

It is quite clear from the above that a great deal of judgment is involved from the very beginning. What criteria will be used in identifying a qualified worker? Is the qualified worker an old timer, a newcomer or someone somewhere in between?

What is normal pace? Is there an objective way of ascertaining what normal is or must the time study man rely on his own judgment?

Should a task be thoroughly standardized before it is time studied? How much experience should the worker have on the job in question before time studies are made? A week? A day? A month?

Are conditions which affect performance time standardized or will there be changes from day to day, depending on circumstances beyond the immediate control of the worker?

These are but a few of the questions which come to mind when considering the task of the time study man. Firm answers must be found for each question because of the nature of time study. That is, a standard set by stopwatch time study is dependent, if it is to have enduring qualities, on preservation of the conditions which obtained at the time the study was made.

In other words, when a time study man studies a job for the purpose of setting a standard he is, in essence, basing his conclusions on a sample of the work in question. He is making a prediction. Based on his sampling of the work, he predicts that a certain level of output can be maintained as long as the job exists, so long as there aren't any changes.

The predictions made by political polsters such as Gallup are analogous. Gallup interviews only a fraction of the population. By interviewing a representative cross section he hopes to be able to predict the outcome of elections or report what is uppermost in people's minds. If his sample is biased or if something happens which causes people to change their minds, his predictions won't hold up.

The same problem holds true in the case of a stopwatch study. If the study is made up out of a biased sample of the operation it applies to or if changes occur after the study has been made, it won't hold up.

It is possible for a time study man to minimize his sampling error by making sure that an operation is thoroughly standardized before it is studied, by making longer studies, by making several studies at various times during the day and week and by checking his studies through the use of statistical sampling formulas.

In actual practice there are very few companies which are conscientious enough about their industrial engineering practices to take care in this respect. Quite frequently union representatives encounter standards based on studies of 10 or 15 minutes duration. Some companies even go so far as to set standards based on studies of 2 or 3 minutes duration. This, of course, is the height of absurdity.

The sampling characteristics of stopwatch studies suggest that the industrial engineer is faced with two problems when he sets out to establish a production standard: (1) he must make a quantitative judgment, i.e., how long should he make his study and, (2) he must make a qualitative judgment, i.e., what is required to assure a representative and unbiased sample.

Within this general context there are a number of specific steps — as follows — which the time study man must take:

(1) After having been instructed to prepare a standard for a particular operation the time study man must, first of all, select the operator who is to be studied.

(2) Then, having decided whom he should study, he next decides when.

(3) Once he has made these decisions he is ready to proceed to the work station he has selected and prepare a detailed record of job circumstances and conditions.

(4) At this time he also writes up a description of the job which outlines the method employed, in detail.

(5) Next, he develops an elemental breakdown of the operation which means that he subdivides each cycle of work according to principles which will be discussed later on.

(6) Now, he is ready to start timing. Using a decimal minute watch, in most cases, he proceeds to make time observations which coincide with his elemental breakdown.

(7) While he is timing the job he is also forming a judgment about the performance level of the operator which he will record on the time study sheet. This is often referred to as rating, leveling, performance rating, efficiency rating or normalizing.

(8) Upon completion of his observations he then makes the computations required to reduce his observations to average time, and to convert average time into "normal" time as per his judgment.

(9) Allowances for personal time, rest time (in some cases) and unavoidable delays are applied. The size of these allowances and their application will be discussed in detail.

The remaining portions of this booklet, in large part, are devoted to an analysis of each of these steps, calling attention to the inherent weaknesses of the procedure, even when industrial engineers adhere to the most favorable techniques.

IV . . . SELECTING THE OPERATOR

"Why is it that the time study man always seems to time the best man in the department when he studies a job?" "Is it right for the time study man to set a standard based on the fastest man on the line?"

These are paraphrases of questions which union representatives hear over and over again as they service local unions where stopwatch time studies are used for the purpose of determining work load. They are illustrative of the widespread suspicion, on the part of workers, that management makes an effort to bias the results of time studies in its favor by selecting the strongest, the most skillful workers as subjects for time studies.

There is ample foundation for this suspicion in many cases. It wasn't too long ago that industrial engineers were using binoculars to make time study observations undetected by the worker. Then there was Frederick Taylor's time study mechanism which looked like a book, thus permitting the industrial engineer to create the impression that he was deeply engrossed in a fascinating murder mystery while in reality he was actually making a time study.

Of course today's industrial engineer would be quick to concede the failings of the past and quick to assert that times have changed. And, many union leaders would support this view. However, it isn't the incompetent or the devious industrial engineer that concerns us. We are willing to assume that most industrial engineers are motivated by a desire to be fair in their determinations.

On the other hand, we are acutely aware of the extent to which judgment influences the results of stopwatch time studies and, where judgment is involved, there are likely to be differing opinions.

Selection of the operator or operators who will be time studied when setting a standard is one of many examples of the influence of judgment.

The worker who feels that the industrial engineer always selects the fastest operator as his subject for a time study may be wrong. The industrial engineer may be selecting a man who only looks like he is the fastest man. His movements may be rapid and his effort level high but the results of his effort may fall short of the worker who appears to be working at a more relaxed pace although, in reality, he is producing more because his motion patterns are more efficient and his movements are well coordinated.

Or, the industrial engineer may pick an operator who is considered "average" only to find that the operator either "runs away" with the job or freezes up under the influence of a form of stage fright induced by the presence of the industrial engineer. Under these circumstances the thoughtful industrial engineer will select another operator who isn't prone to abnormal behavior when being observed at work. Unfortunately, at least a few time study men will "bull" their way through a study under these circumstances claiming that they can compensate for either stimulated or anesthetized performance through their rating factor. As we shall see when we undertake an analysis of rating, this only compounds the problem by imposing one layer of judgment on another.

Actually, there is no objective way of selecting an operator for time study purposes. The best we can do is exercise the combined judgment of the foreman and the departmental steward in an effort to make as reasonable a selection as possible. In doing so the natural skills of the worker must be considered along with his over-all experience as well as his familiarity with the job in question.

V . . . RECORDING JOB CIRCUMSTANCES AND CONDITIONS

Having selected the operator, the industrial engineer then must decide when the study is to be made, i.e., what time of the day and what day of the week. In some cases this decision may not have a particularly critical effect on performance time. Nevertheless, it is a factor which needs to be considered. The operator's effort level and/or pace will vary throughout the day, especially in the case of jobs involving a high degree of physical strain. And, various factors outside the control of the operator often influence performance time in differing degrees depending on the time of the day or the day of the week.

Next, the industrial engineer proceeds with the preparation of a record of all job circumstances and conditions which have or may have an influence on performance time. The importance of this phase of the procedure is often overlooked by industrial engineers and workers alike. Management, ever anxious to reduce costs, pressures the industrial engineer on the productivity question just as it pressures workers in the shop. The lower the cost of setting standards the better management likes it. This leads the industrial engineer to the adoption of short cuts and sloppy procedure.

Evidence of this is most apparent in connection with records of job circumstances and conditions. Examination of hundreds of time study work sheets indicates that very few industrial engineers are careful in this respect.

For instance, it is rare to find work sheets which are informative enough to permit a stranger to even identify the equipment involved let alone locate the work station. And yet, this is precisely what is required. If these records are going to be useful as a source of documentation for future reference they must be complete enough to permit a person unfamiliar with the work station, material, equipment, etc., to identify all of these items by mere examination of the work sheets.

The fundamental importance of this phase of the procedure becomes apparent, unfortunately, only after it is too late. Time after time industrial engineers and shop stewards have reached an impasse in discussion of work load grievances because the time study records are incomplete. The industrial engineer argues that the work place was laid out just as it is now, at the time the original study was made, and the steward argues that the work station layout has been altered or vice versa.

If the industrial engineer had taken the trouble to prepare complete records when he made his original study, the argument could be easily resolved. Instead, the matter resolves itself into a dispute over who has the best memory, the steward or the industrial engineer. This is sheer nonsense.

The type of information which must be recorded in order to provide adequate records will vary depending on the work being studied.

Generally speaking this record should include a complete identification of the material involved, e.g., 10-20 cold rolled steel, a detailed description of the tools and equipment, the work area, lighting, ventilation, heat, cold, noise, and so on.

Many work sheets make provision for a diagrammatic sketch of the work place and layout. When linear relationships between the operator, worked and unworked material, and equipment are specified, this visual record can become very valuable.

Some companies have started taking photographs of the workplace which are attached to the time study sheet.

At the risk of belaboring the point, the importance of preparing a detailed record of job circumstances and conditions warrants re-emphasis. As previously reported, the reliability and durability of a job standard is contingent upon preservation of standardized conditions.

What may appear to be a relatively minor change may have a major effect on performance time. Verification of changes, however, depends on the extent to which the industrial engineer's records are clear and complete. If they are "out of focus" they will not be helpful in resolving disputes.

JOB DESCRIPTION

Now, the industrial engineer is ready to write up a description of the job he is going to time study. This requires him to prepare a detailed analysis of the method employed in completing a process or bringing material from an unworked to a worked stage.

The process may be entirely manual in character, it may involve some degree of mechanical control or it may be almost entirely automatic. In any case, it should be possible to complete a work cycle simply by following the industrial engineer's description of the process and method employed in performing the task.

Unfortunately, many industrial engineers are inclined to assume a good deal and take a lot for granted in writing up their job descriptions. After all, they are familiar with the work. So they use their own particular brand of "shorthand" in making notes or they prepare only the sketchiest of descriptions. Consequently, only those who are intimately acquainted with the work involved have a vivid recollection of the method employed.

There have been enough work load disputes over alleged methods changes which couldn't be resolved by reference to the facts to make it crystal clear that the record must be complete.

Even when the record is complete, problems will still arise. Some companies have methods analysts who prescribe the method for a job before a time study is made. Others leave it up to the foreman and/or worker to decide what the method should be. While good industrial engineering practice requires determination of method prior to setting a standard there are many, many companies which do not follow this practice.

At least a few companies set only temporary standards on new jobs so that they will have an opportunity to benefit from the skill and ingenuity of the worker before a permanent standard is established. This is an irritant because it means that the worker has to assume a responsibility which management claims as its own, i.e., method determination, without appropriate compensation.

The industrial engineer has one more task to fulfill and then he will be ready to start timing the job. Normally, he will prepare an elemental breakdown of the work cycle for the purpose of separating manual elements from machine control elements and constant elements from variable elements.

VI . . . ELEMENTAL BREAKDOWN

The job description the industrial engineer has prepared is supposed to represent a word picture of all the work required (1) to bring a piece of material from an unworked to a worked stage, (2) to complete a portion of an assembly line operation or (3) to complete a process.

In some cases this description will be brief and simple because the work cycle is brief and simple; in other cases it will be long and complex.

In any event the industrial engineer will normally attempt to convert the work cycle into elements, each of which represents what is presumed to be a logical subdivision of the whole. One element may include all work performed in preparing material for assembly, machining, treating or processing. Another element may encompass all processing or machining and a third element may include all work required to dispose of the finished product or assembly.

Thus, a work cycle which calls for drilling a half inch diameter hole in a piece of cast iron 4"x4"x½" might require an elemental description which does no more than separate manual elements from machine elements. In that event the elemental description would look something like the description recorded on work sheet No. 1.

This description leaves a great many questions unanswered which must be answered elsewhere on the time study work sheet. Nevertheless it does demonstrate how a simple elemental breakdown would appear.

If the job described in our example involved holding to size, such as $\pm$ .005 inches, it is likely that inspection would be required. In extremely sensitive work inspection might be required for every piece. In that case we would add a fourth element which would describe the inspection process. This requires revision of element three as illustrated by work sheet No. 2.

Each of the four elements included in the elemental breakdown is cyclical or repetitive in character. That is, each element is performed every time a piece is brought from an unworked to a worked state. A work cycle is incomplete until each element has been performed.

The picture would change, however, if inspection was required every 10 pieces rather than every piece. Then the complete cycle would consist of three elements during the machining of nine pieces and four elements during machining of the tenth piece.

This introduces what is commonly referred to as the non-cyclical or non-repetitive element. It is still regular enough in occurrence to be treated as an integral part of the elemental description but it is not repetitive in the same sense that the other elements are.

Converting the inspection element from a cyclical to a non-cyclical element may also require revised treatment of the unloading and disposing element since non-cyclical inspection would alter the third element every 10th piece. This suggests the need for splitting the third element into two elements, one consisting of stopping the machine and unlocking and unloading

Timed By ______ Checked By ______ Workplace or Mach. ______ Mach. No. ______

Operators Name ______ Clock No. ______ Material ______ R.P.M. ______

Time Study No. ______ Dept. No. ______ Lubricant ______ Strokes Per Min. ______

Special Tools Used ______ Feed ______

Part Name ______ Part No. ______ Operation No. ______

Remarks ______

SKETCH	DETAILED DESCRIPTIONS OF ELEMENTS
	(1) Pick up unworked piece with left hand and position in fixture; tighten fixture with right hand; start machine with left hand; run down drill with right hand; engage automatic feed with right hand
	(2) Drill through ½" diameter hole; automatic feed kicks out
	(3) Stop machine with left hand; unlock fixture with right hand; remove worked piece from fixture with left hand; dispose of worked piece with left hand; grasp unworked piece with left hand

Work Sheet No. 1

Timed By ______ Checked By ______ Workplace or Mach. ______ Mach. No. ______

Operators Name ______ Clock No. ______ Material ______ R.P.M. ______

Time Study No. ______ Dept. No. ______ Lubricant ______ Strokes Per Min. ______

Special Tools Used ______ Feed ______

Part Name ______ Part No. ______ Operation No. ______

Remarks ______

SKETCH	DETAILED DESCRIPTIONS OF ELEMENTS
	(1) Pick up unworked piece with left hand and position in fixture; tighten fixture with right hand; start machine with left hand; run down drill with right hand; engage automatic feed with right hand
	(2) Drill through ½" diameter hole; automatic feed kicks out
	(3) Stop machine with left hand; unlock fixture with right hand; remove worked piece from fixture with left hand
	(4) Pick up go-no-go gauge with right hand; inspect worked piece holding piece in left hand and gauge in right hand; aside gauge with right hand; aside piece with left hand; reach for and grasp unworked piece with left hand

Work Sheet No. 2

the fixture and the other consisting of disposing of the piece. Unfortunately this treatment of the problem introduces another problem, i.e., timing of extremely short elements. We will comment on this matter shortly.

There is still a third type of element which may occur and that is the foreign element or irregular element. During the course of the time study observation the operator may leave his work station briefly to obtain stock, get a drink of water, go to the restroom, speak to the foreman, etc. Or, he may have to interrupt the cyclical elements to replace the bit, remove chips, clean the work station, clear the way for aisle traffic, make minor machine adjustments, etc.

When these or similar events occur the industrial engineer records and times them in space provided for foreign elements. He more than likely will not time them as cyclical or non-cyclical elements because, even though they may be an integral part of the operation, they are not predictable in the same sense as are the cyclical and non-cyclical elements.

Upon completion of the study he will have to evaluate the foreign elements he has timed to determine how they should be treated. If the operator took time during the study to satisfy personal needs, the time study man will ignore the recorded time on the assumption that personal allowances will provide time to cover this problem.

Other foreign elements may be included in the unavoidable delay allowance. In some cases a separate standard may be indicated as in the case of tool changes. If the operator obtains and disposes of his own stock, the time study man will more than likely choose one of two alternatives, i.e., pro-rating stock time by creating another non-cyclical element or creating a separate standard.

The example we have been using is relatively simple and unencumbered. Some work cycles will consist of dozens of elements. Bench molding is a good example of a type of operation where there often are as high as 40 elements. Nevertheless, the basic principles are the same — separate machine from manual elements and constant from variable elements. Hopefully, in any event, there will be some logical reason for a given elemental breakdown. Elemental breakdowns should serve as a means to an end and not an end in themselves.

Management generally looks upon elemental breakdowns as an aid to method analysis among other things. The conversion of a job into interrelated parts of the whole presumably makes it easier for management to see where methods improvement is needed. It should be emphasized that regardless of the reason management may have for preparing an elemental breakdown, the process adds nothing to the accuracy of the results.

Trade unionists also have a stake in this process, particularly when it comes to protecting earnings built up through experience and ingenuity.

Many union contracts contain language which limits companies to changing existing standards only when the company has initiated changes which affect performance time and then only those elements affected by the change can be altered by the company. In this sense the more elements the merrier.

But, as is often the case with work measurement, there are also drawbacks. When an industrial engineer subdivides wholly manual portions of a job, he is indulging in the erroneous assumption that the various parts of a job possess unique and distinct characteristics unrelated to the whole. This assumption is harmless enough when the industrial engineer confines himself to rating manual effort as a whole but it becomes highly questionable when he attempts to rate each manual element separately.

Industrial engineers also burden their quasi-scientific profession when they attempt "micromotion" analysis while setting standards with the stopwatch. In some cases circumstances require establishment of elements of very short duration. For the most part, though, this is not the case. Certainly, elements of less than .05 minutes duration should be combined with other elements whenever possible. This is particularly true where a number of very short elements occur in succession.

It simply isn't possible for even the most experienced time study man to observe the elemental break-off point, read his watch, record his reading and focus his eyes in preparation for reading the next break-off point where elements are less than .05 minutes long.

Some time study men take great pride in asserting their ability to time short elements in quick succession. An experienced industrial engineer who is familiar with the processes which are characteristic in his place of employment may be able to handle a stopwatch somewhat more proficiently than an inexperienced person, but this experience only gives him an edge up to a certain point. Then most people have exceeded their physical limitations.

VII . . . THE STOPWATCH

So far we have seen that at every turn the industrial engineer is required to use his judgment. Management's effort to rid itself of the "primitive" method of determining work load, i.e., rule-of-thumb decisions, has resulted in cloaking the process in "respectable" attire, but underneath there is still the same old body.

The industrial engineer, in spite of all his professional training, must still rely on his judgment in answering the most fundamental questions concerning work measurement. He cannot claim scientific verification for his answers to such questions as, "Which operator or operators should I study?" "When should I make my study?" "How long should I study the job?" "Under what conditions will the job be operating 'normally'?" "What job circumstances and conditions will influence performance time?"

However, when it comes to the actual mechanics of timing a job it would seem that the industrial engineer has finally managed to free himself from the quagmire of judgment, opinion and speculation which has restricted his profession heretofore.

At this point in the work measurement process the industrial engineer, having completed all preliminary preparations, measures the performance of the worker with a timing device, usually a stopwatch, which is, in and of itself, quite accurate. A good stopwatch, for instance, will not lose or gain more than one or two seconds in an hour. Certainly, from the point of view of work measurement, this is a highly acceptable degree of accuracy.

Nevertheless, as we shall see, even the theoretical perfection attainable at this stage of the process is marred, both because of the limitations of the measuring instrument and the limitations of the measuring instrument user.

The most common measuring instrument in use today is the decimal-minute stopwatch reading in either hundredths (.01) or thousandths (.001) of a minute and the decimal-hour stopwatch reading in ten thousandths (.0001) of an hour. Of the three the most popular is the decimal-minute watch reading in hundredths (.01) of a minute. This popularity stems from the fact that the latter is easier to read and the results are easier to record, in contrast with both the decimal-minute (.001) and decimal-hour (.0001) watches.

It is easier to read the decimal-minute (.01) watch because it takes the sweep hand of this watch one minute to circle the dial while only requiring six seconds for the decimal-minute (.001) watch and thirty-six seconds for the decimal-hour (.0001) watch. Obviously it is less difficult to read and record elapsed time when the sweep hand is moving at a slower speed.

The basic unit of measure represented on the dial of a decimal-minute watch (.01) is the equivalent of one hundredth of a minute. Written as a fraction, one hundredth of a minute is expressed as one over one hundred or 1/100. Written as a decimal, one hundredth of a minute equals 0.01.

Thus, .10 is equal to ten hundredths of a minute; .25 is equal to twenty-five hundredths of a minute; .46 is equal to forty-six hundredths of a minute; 2.66 is equal to two hundred and sixty-six hundredths or two minutes and sixty-six hundredths minutes, and so on.

Ordinarily, the industrial engineer will have his stopwatch mounted at the top of a clipboard which also serves as a writing surface.

Holding the clipboard in a position which permits him to view the job and the watch with a minimum of eye movement, the time study man proceeds to time the operation. Usually he will time the first piece, process or assembly, i.e., if his study coincides with the beginning of a shift or model run. He will wait until the operator has completed several cycles (depending on the length of the cycle, of course) and then begin timing.

The time study man presumably starts his watch just as the operator completes one cycle and commences another. If he is cycle-timing he will record elapsed time only once each cycle. This would be the case where an elemental breakdown is neither indicated nor justified.

Normally, however, the industrial engineer will have prepared an elemental breakdown which involves dividing the job cycle into its component parts. In an earlier section we used the example of a job which involved drilling a hole one-half inch through. Disregarding the non-cyclical inspection element our example called for three elements as illustrated by work sheet No. 3.

In this example the time study man would start his watch just as the operator released the worked piece. He would then make three recordings each cycle, i.e., each time a piece was brought from an unworked to a worked stage. His *first reading and recording* would coincide with the *engagement of the automatic feed* at the conclusion of the first element. His *second* reading and recording would occur when the *automatic feed kicked out* at the end of element number two, and his *third* reading and recording would be made at the *conclusion of the third element,* i.e., when the piece is released in the box.

It is clear that the time study man will be kept pretty busy during the course of timing a job, particularly when the elements are all short. First he must *recognize* the elemental break-off or reading point. Then he must instantaneously *read* his stopwatch, and, finally, he must *record* his reading.

In addition to all this he must remain alert to the possibility that foreign elements will enter the picture and he must also evaluate the performance he is observing so that he will be prepared to rate or level the observed time.

This means that the time study man is busier than the proverbial "cat on a hot tin roof." It also means that unintentional errors may creep into the picture.

Ralph Presgrave, writing in his book entitled, "*The Dynamics of Time Study*,"[1] calls attention to the fact that even though the stopwatch itself may be relatively accurate, errors of some significance can be anticipated.

Observing that the stopwatch is a relatively accurate measuring instrument, Presgrave takes note of the tendency to carry this thought over into

1. The University of Toronto Press, Toronto, Canada, 1944, p. 38.

Timed By ______ Checked By ______ Workplace or Mach. ______ Mach. No. ______

Operators Name ______ Clock No. ______ Material ______ R.P.M. ______

Time Study No. ______ Dept. No. ______ Lubricant ______ Strokes Per Min. ______

Special Tools Used ______ Feed ______

Part Name ______ Part No. ______ Operation No. ______

Remarks ______

SKETCH	DETAILED DESCRIPTIONS OF ELEMENTS
	(1) Pick up unworked piece with left hand and position in fixture; tighten fixture with right hand; start machine with left hand; run down drill with right hand; engage automatic feed with right hand
	(2) Drill through ½" diameter hole; automatic feed kicks out
	(3) Stop machine with left hand; unlock fixture with right hand; remove worked piece from fixture with left hand; dispose of worked piece with left hand; grasp unworked piece with left hand

Work Sheet No. 3

time study by assuming that recorded elemental times are also equally accurate. Presgrave argues that this assumption is unjustified, claiming that an element recorded as .10 minutes will have an actual value of between .095 and .105 minutes, a condition which introduces an error of plus or minus five percent.

There is another aspect of the actual timing of a job which requires consideration.

VIII . . . TIMING METHOD

While in the process of timing the job, the time study man has a choice of method. He can elect to use the continuous method of timing or the snap back method.

If he chooses the former, he starts his watch at the beginning of the study and lets it run until he has concluded the study. Thus each successive recording represents both the elemental break-off point and total elapsed time.

If he chooses the latter, each time he reads the watch he simultaneously and instantaneously returns the sweep hand to zero. Under these circumstances the successive readings represent only elapsed time for one element of one cycle. Total elapsed time is not accumulated on the watch.

There are arguments both for and against each of these timing procedures. In some cases, for example, it is impractical to use the continuous method. This might very well be the case where the industrial engineer is timing only one of many elements of a job which has a very long cycle.

Where the snap-back method is employed it is also much easier to time transposed elements. When an operator performs elements out of sequence, and this is not uncommon, the observer using the continuous method will have difficulty with his recordings.

In addition the observer using the snap-back technique has an opportunity to compare elemental values from one cycle to the next without performing a series of subtractions which would only complicate his task. This comparison will give the observer an assumed clue as to how long his study should be.

Many time study men also use these comparisons to evaluate operator performance. If elapsed times seem to be relatively consistent, the observer assumes that the operator is demonstrating good method and good effort. If the elapsed times are relatively inconsistent, the observer is inclined to assume that the operator is not giving satisfactory performance. Consistency is "rewarded" with a comparatively high rating and inconsistency is "punished" via a comparatively low rating.

Some time study men prefer the snap-back method for various reasons and attribute a degree of accuracy to it equal to the continuous method. For one thing it eliminates a good deal of arithmetic because each recording represents elapsed time for a single element rather than cumulative time. Where the continuous method is used, the figures he records are cumulative figures. Elapsed times for each element are derived by subtracting one cumulative recording from a subsequent recording. If the study is a long study consisting of several elements, the calculations required are considerable.

The problem can be illustrated by worksheets No. 4, No. 5 and No. 6 which set forth a very simple study consisting of three elements: (1) pick-up, load and lock; (2) drill; (3) unlock, unload, lay aside.

Reading from left to right and down on worksheet No. 4 we can see that each recording represents a cumulative reading and that the total

TIME STUDY OBSERVATION

DATE ______

TIME START ______ A.M. P.M. ______

TIME STOP ______ A.M. P.M. ______

ELAPSED TIME ______

NUMB. PIECES ______

SHEET NO. ______

NO. SHEETS ______

NUMBER / NOTES	Line	ELEMENTS (1) PICK-UP, LOAD AND LOCK T	(1) R	(2) DRILL T	(2) R	(3) UNLOCK, UNLOAD, LAY ASIDE T	(3) R
	1		.10		.48		.55
	2		.64		.99		1.06
	3		1.16		1.56		1.64
	4		1.75		2.12		2.19
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	13						
	14						
	15						
	16						

SUMMARY

	(1)	(2)	(3)
Total Time			
No. of Readings			
Av. of Readings			
Frequency			
Average Time			
El. Rating Factor			
El. Normal Time			

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A			
B			
C			
D			
E			
F			
G			
H			
I			

Av. Cycle Time ______
Cycle Rating Factor ______
Normal Cycle Time ______

Percent Allowances

Pers.	Fat.	Delay	Total

Std. Time Per Unit ______
Pieces Per Hour ______
Std. Hours Per 100 ______

Allowances in Minutes

Pers.	Fat.	Delay	Total

Avail. Prod. Min. Per Hr. ______
Pieces Per Hour ______
Std. Hrs. Per 100 ______

Work Sheet No. 4

TIME STUDY OBSERVATION

DATE ____________

TIME START ________ A.M. P.M. ____

TIME STOP ________ A.M. P.M. ____

ELAPSED TIME ____________

NUMB. PIECES ____________

SHEET NO. ________

NO. SHEETS ________

NUMBER		ELEMENTS PICK-UP, LOAD AND LOCK (1)		DRILL (2)		UNLOCK, UNLOAD LAY ASIDE (3)																							
NOTES	Line	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R
	1	10	.10	38	.48	07	.55																						
	2	09	.64	35	.99	07	1.06																						
	3	10	1.16	40	1.56	08	1.64																						
	4	11	1.75	37	2.12	07	2.19																						
	5																												
	6																												
	7																												
	8																												
	9																												
	10																												
	11																												
	12																												
	13																												
	14																												
	15																												
	16																												

SUMMARY

Total Time														
No. of Readings														
Av. of Readings														
Frequency														
Average Time														
El. Rating Factor														
El. Normal Time														

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A			
B			
C			
D			
E			
F			
G			
H			
I			

Av. Cycle Time ________

Cycle Rating Factor ________

Normal Cycle Time ________

Percent Allowances

Pers.	Fat.	Delay	Total

Std. Time Per Unit ________

Pieces Per Hour ________

Std. Hours Per 100 ________

Allowances in Minutes

Pers.	Fat.	Delay	Total

Avail. Prod. Min. Per Hr. ________

Pieces Per Hour ________

Std. Hrs. Per 100 ________

Work Sheet No. 5

TIME STUDY OBSERVATION

DATE________

TIME START______ A.M. P.M.____

TIME STOP______ A.M. P.M.____

ELAPSED TIME________

NUMB. PIECES________

SHEET NO.____

NO. SHEETS____

ELEMENTS: (1) PICK-UP, LOAD AND LOCK; (2) DRILL; (3) UNLOCK, UNLOAD, LAY ASIDE

NUMBER / NOTES	Line	(1) T	(1) R	(2) T	(2) R	(3) T	(3) R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R
	1	10		38		07																							
	2	09		35		07																							
	3	10		40		08																							
	4	11		37		07																							
	5																												
	6																												
	7																												
	8																												
	9																												
	10																												
	11																												
	12																												
	13																												
	14																												
	15																												
	16																												

SUMMARY

	(1)	(2)	(3)											
Total Time														
No. of Readings														
Av. of Readings														
Frequency														
Average Time														
El. Rating Factor														
El. Normal Time														

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A			
B			
C			
D			
E			
F			
G			
H			
I			

Av. Cycle Time ______

Cycle Rating Factor ______

Normal Cycle Time ______

Percent Allowances

Pers.	Fat.	Delay	Total

Std. Time Per Unit ______

Pieces Per Hour ______

Std. Hours Per 100 ______

Allowances in Minutes

Pers.	Fat.	Delay	Total

Avail. Prod. Min. Per Hr. ______

Pieces Per Hour ______

Std. Hrs. Per 100 ______

Work Sheet No. 6

elapsed time for the study was 2.19 minutes. We can also see that in order to derive elapsed time for each elemental reading it is necessary to subtract .00 from .10, .10 from .48, .48 from .55, .55 from .64, .64 from .99, and so on.

When all subtractions have been performed, as illustrated by worksheet No. 5, the time study sheet contains two sets of figures, one representing cumulative times and the other representing elapsed times.

If the time study man had used the snap-back method he would, *in theory at least,* have gotten exactly the same end result by recording only elapsed times while, at the same time, relieving himself of the extra arithmetic. A snap-back study would, using the same example, appear as illustrated by worksheet No. 6.

However, in actual practice, there are valid criticisms of the snap-back method of timing which rule it out as an acceptable timing method except under special and limited circumstances.

Among other things, short elements are very difficult to time with an acceptable degree of accuracy. Short elements are difficult to time under the best of circumstances anyway.

Errors will also go undetected. If the time study man records .08 when he should have recorded .10 there is no way of knowing this when he is using the snap-back method.

It is also possible to leave out vital parts of the study by neglecting to record foreign elements or elements which appear to be extraordinarily long.

There is, in addition, the time lost while snapping the hand back to zero. While this might seem like a minor factor, Lowry, Maynard and Stegemerten report that the cumulative error from this source — in an element of .10 minutes duration — averages 3.8%. That is, the time study engineer's total time will fall short of the actual time by 3.8%.

Lowry, Maynard and Stegemerten further report that the reaction time of the observer will result in an error ranging between 2% and 9% depending on the length of the cycle.[1] Obviously, the more recordings there are within a given period of time the more error there will be from this source.

In an experiment involving a number of trained time study men Adam Abruzzi found that those using the continuous method recorded total elapsed time of 2.25 minutes for 20 cycles while those using the snap-back method recorded elapsed time of 1.97 minutes.

This means that every 20 cycles .28 minutes was lost. Divide the total actual elapsed time for 20 cycles (2.25 minutes) into 60 and we determine how many times each hour the .28 minutes loss would occur. ($60 \div 2.25 = 26.6$). Take $26.6 \times .28 \times 8$ and we get *59.6 minutes lost each day* where the snap-back method was used.

1. S. M. Lowry, H. B. Maynard, and G. J. Stegemerten, *Time and Motion Study,* 3rd Edition, McGraw-Hill Book Co., New York, 1940, pp. 191-192.

Some industrial engineers pooh-pooh this criticism. They claim that the experienced time study man can handle a stopwatch so well that this problem is virtually eliminated. But research, tests and experience have shown that the errors described above are made by experienced time study men.

One further word on this subject and then we will move on to another phase of the stopwatch time study process.

Earlier we indicated that some industrial engineers like the snap-back method because they feel that having the elapsed times for each element in front of them helps in evaluating the operator's performance. Consistent times for an element are supposed to reflect good effort and method. Inconsistent times are supposed to reflect poor method and poor effort. It is possible that these assumptions may be valid but it is also equally possible that consistent or inconsistent elapsed time could have nothing to do with the operator's effort level or method. Material variation, equipment vagaries, external interference, these and a dozen other conditions could produce the same symptoms.

IX . . . "NORMALIZING"

This brings us to another phase of work measurement. Without question it is one of the most troublesome aspects of the whole procedure. We are referring to what is variously called normalizing, leveling, rating, effort leveling, speed rating, pace rating and "objective" rating.

Whatever the designation, with minor variations on the theme, the objective is the same. In stop-watch time study, as with *all* types of work measurement, it is necessary to adopt some procedure for "normalizing" the time data because of the wide variation in the speed at which different operators work. Recorded elemental or cyclical time values must be adjusted to reflect the time required for the "normal" worker working at a "normal" pace to complete a work cycle.

The time study man does not assume that a worker is working at a "normal" daywork pace during a time study. He may be working at that pace or he may be working above or below it.

Actually, the range or variation in work pace may be quite substantial. Lowry, Maynard and Stegemerten estimate that the variation is on the order of 2.76 to 1.[1] David Wechsler assumes that there is a variation in human capacities of 2 to 2.5 to 1.[2]

Not only is there a wide variation in human capabilities which the industrial engineer must somehow manage to quantify but there is the question of relating this range to some sort of a norm. In other words, before we can say that a worker's performance is above or below normal we have to know what normal is. And that, to say the least, is the $64 question.

Our engineers and scientists have developed propulsion and control systems so sophisticated that space shots can be made which display accuracy incomprehensible to the layman.

Medical science has made miraculous strides toward eradication of crippling and fatal diseases.

Industry has employed modern technology to produce synthetic products which we hardly dared dream about a few short years ago.

But do we know any more about what "normal" is today than we did 10, 50 or 100 years ago? The answer is an emphatic no!

Various attempts have been made to establish a universal concept of normal. Predetermined motion time systems assume that there is such a concept. However, by and large, normal is a concept which resides in the mind of the industrial engineer. He may fortify his concept with guidelines or benchmarks, but the benchmarks themselves simply represent someone else's concept of normal. There are no scientific, objective criteria he can refer to.

1. S. M. Lowry, H. B. Maynard, and G. J. Stegemerten, *Time and Motion Study*, 3rd Edition, McGraw-Hill Book Co., New York, 1940, p. 209.
2. David Wechsler, *Range of Human Capacities*, 2nd Edition, Williams and Wilkins Co., Baltimore, 1952, p. 69.

Judgment is the main ingredient, then, in "normalizing." There is no way of imparting validity to this process. In this respect, it's knowing what is acceptable that counts. No wage incentive system and/or no work measurement system will survive if the industrial engineer has failed in his estimate of what is acceptable as a measure of "normal" performance.

No other aspect of work measurement has evoked so much soul searching, so much twisting, so much kicking and squirming as has the problem of identifying the "normal" operator.

Ever since the turn of the century, when Frederick W. Taylor fathered the stopwatch time study approach to determining work load there has been a deep and abiding interest in devising a scientific means of establishing standards which properly reflect the capacity of the normal or average worker.

Taylor himself had no doubts about his capacity to resolve the issue. In his *Shop Management* he wrote:

"The writer has found it best to take his time observations on first-class men only, when they can be found; and these men should be timed when working at their best. Having obtained the best time of a first-class man, it is a simple matter to determine the percentage which an average man will fall short of this maximum."[1]

Or, if you prefer, take these words of Taylor, offered as a part of his testimony before a Congressional Committee engaged in an investigation of the then burgeoning field of "scientific management."

". . . We first take a good man, not a poor man — we always try to take a man well suited to his work. We then assure ourselves that that man is working at a proper rate of speed; that is, that he is not soldiering on the one hand, and that on the other hand he is not going at a speed which he cannot keep up year in and year out without undue exertion. We then determine as accurately as we know how the proper speed for doing the work . . ."[2]

While Taylor was satisfied that the practice of establishing work standards based on time studies of "first-class" workers was valid, others were not. As a matter of fact there was such widespread revulsion to this that the practice was gradually abandoned.

By 1920 the *terminology* employed in "scientific management" had been modified to the extent that time study men no longer spoke of the "first-class" operator but, instead, spoke of the "normal" or "average" operator. The word *terminology* must be emphasized because even though the words were changed there is no evidence that, at that time, a practical means of implementing the change had been devised.

LEVELING

Actually, it wasn't until 1927, when Lowry, Maynard and Stegemerten publicized the results of their work for Westinghouse, that a methodology was claimed to have been developed for implementing the concept of "normal" performance. Writing in *Time and Motion Study* the three aforementioned author-practitioners had this to say:

1. F. W. Taylor, *Shop Management*, Harper and Brothers, New York, 1903.
2. *Hearings Before Social Committee of the House of Representatives to Investigate the Taylor and Other Systems of Shop Management under the Authority of H. Res. 90;* Vol. III, 1912.

". . . In order to set equitable time standards for doing any task, it is necessary to establish certain criteria for performance. To this end, a normal reasonable performance called the average performance has been arbitrarily established by definition. It is the performance given by the operator who works with average effort and who possesses average skill . . . It should be clearly understood that when the time-study man speaks of the average performance in a given occupation, he has in mind not the average of all human beings, or even the average of all persons engaged in that occupation. The average performance is established by definition and not statistically and represents the time-study man's conception of a normal, standard working performance which may reasonably be expected from anyone qualified for the work at hand."[1]

Their method, based on the above description of what is required in order to "set equitable time standards," consisted of a process called *leveling* which required the time study man to evaluate operator performance in terms of four factors: (1) skill, (2) effort, (3) conditions and, (4) consistency.

At least one version of the Lowry, Maynard and Stegemerten system of "normalizing" further subdivided the process by requiring the time study man to distinguish eighteen degrees of skill, eighteen degrees of effort, six degrees of conditions and six degrees of consistency.

Skill, which was defined as "proficiency at following a given method," was subdivided as follows:

Super Skill	+.15	+.14	+.13
Excellent Skill	+.11	+.095	+.08
Good Skill	+.06	+.045	+.03
Average Skill		.00	
Fair Skill	−.05	−.075	−.10
Poor Skill	−.16	−.19	−.22

If the time study man believes that the operator under observation qualifies as super skilled to the nth degree he gives credit for a +.15 or plus 15%. If, on the other hand, the observer believes that the operator is hopelessly clumsy he imposes a penalty of −.22 or minus 22%. The observer, depending on his judgment, may also select any of the degrees of skill falling between these extremes.

It is interesting, in this connection, to take note of the description of super skill and poor skill which the observer must work by.

Super skill is defined as: "The operator of excellent skill perfected — has been at work for years — naturally suited to the work — works like a machine — motions so quick and smooth they are hard to follow — does not seem to have to think about what he is doing — elements of operation blend into one another so that division points are difficult to recognize — conspicuously the best worker of all."

In contrast poor skill is defined as: "New man or misfit — unfamiliar with the work — uncertain of proper sequence of operations — hesitates

1. S. M. Lowry, H. B. Maynard, and G. J. Stegemerten, *Time and Motion Study,* 3rd Edition, McGraw-Hill Book Co., New York, 1940.

between operations — makes many errors — movements clumsy and awkward — does not coordinate mind and hands — lacks self-confidence — can not read drawings well — unable to think for himself."

In "shop" language according to these definitions we could call the super skilled worker a "hot shot" and the poor skill worker "all thumbs."

Curiously enough the worker who is "conspicuously the best worker" in the place doesn't get as much credit, in relation to the worker of average skill, as the worst worker loses in this relation.

For instance, if average observed time came to 1.00″ (one minute) per piece, the leveled time in the case of the top super skilled worker would be 1.15″ and in the case of the worst worker 0.78″ or seventy-eight hundredths minutes. In this example the reward for being the very best worker in the shop in terms of skill is fifteen hundredths of a minute while the penalty for being the very worst worker is twenty-two hundredths of a minute. Evidently virtue is not to be rewarded as highly as lack of virtue is to be punished.

One might further question the assumption that it is possible to level skill to begin with. The problems inherent in leveling skill are illuminated by the following quotes from *Methods-Time Measurement,* a book authored by Maynard, Stegemerten and Schwab.

"Skill is another term that can cause confusion if it is not carefully defined. A common definition is 'knowledge plus ability.' This is entirely too intangible for the purpose of leveling and in addition includes method in its meaning. It is impracticable to attempt to make adjustments by leveling factors for differences in time that are caused by variations in method. Therefore, 'skill' must at all times be defined in its narrow sense of 'proficiency at following a given method' when used in connection with leveling."[1]

But, even this definition raises as many questions as it answers because, "in the light of the findings thus far, there are as many different methods of performing an operation as there are operators doing the job. No two operators perform in exactly the same way . . ."[2]

Obviously, if skill is defined as "proficiency at following a given method" and "there are as many different methods . . . as there are operators" we have the makings of an irreconcilable conflict.

Similar questions can be raised with respect to leveling effort. Here again we have an eighteen degree subdivision to guide the time study man in evaluating operator performance. The subdivision follows:

Excessive Effort	+.13	+.125	+.12
Excellent Effort	+.10	+.09	+.08
Good Effort	+.05	+.035	+.02
Average Effort		.00	
Fair Effort	−.04	−.06	−.08
Poor Effort	−.12	−.145	−.17

1. H. B. Maynard, G. J. Stegemerten, and J. L. Schwab, *Methods-Time Measurement,* McGraw-Hill Book Company, New York, 1948, p. 276.
2. Ibid., p. 281.

Excessive effort is described as a level of exertion which requires the worker to "Extend himself to a pace impossible to maintain steadily — best effort from every standpoint but that of health."

Poor effort, on the other hand, is defined in these terms: "Obviously kills time — lacks interest in work — resents suggestions — works slowly and appears lazy — attempts to extend time through improper method by: (a) making unnecessary trips for tools and supplies, (b) making two motions where one would do, (c) having poor setup or workplace layout, (d) doing work more accurately than necessary, and (e) purposely using wrong or poor tools."

Here again one wonders at the quantification of these extremes of effort. The man working at a killing pace is leveled at a +.13 or plus 13%. The man who is an obvious goldbrick is leveled at a −.17 or minus 17%. Reverting to our earlier example, i.e., average observed time per piece equal to 1.00", we would derive a leveled time of 1.13" for the best effort and .83" for the poorest effort. Something is amiss when a man working at a killing pace gets only a plus thirteen hundredths of a minute in relation to average while the man who is darn near standing still is penalized by seventeen hundredths of a minute.

How does the time study observer know when a worker is performing at one of the eighteen degrees of effort quantified in the system? Very simple. He evaluates observed performance in relationship to average effort. What is average effort?

"The average effort falls on the border line between the fair and the good effort. It is the effort to which all others are compared, and yet it is perhaps the hardest to define specifically. It is a little better than fair effort and a little below the good." [1]

OTHER APPROACHES

Since the development of the "normalizing" methodology described above there have been numerous refinements although basically each new development has been no more than a variation of the same theme.

While the leveling approach to normalizing is still employed by some industrial engineers there has been a gradual realization that it is unrealistic to attempt an evaluation of operator performance which requires the observer to distinguish between eighteen degrees of skill, eighteen degrees of effort, six degrees of conditions and six degrees of consistency.

The difficulties involved in "normalizing" observed performance are illustrated by the words used in describing the process. The Society for the Advancement of Management — a management organization which has devoted considerable time to this problem — says, "Rating is that process during which the time study engineer compares the performance of the operator under observation with the observer's own concept of normal performance." [2]

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1. S. M. Lowry, H. B. Maynard, and G. J. Stegemerten, *Time and Motion Study*, 3rd Edition, McGraw-Hill Book Co., New York, 1940.
2. Society for the Advancement of Management, Committee on Rating of Time Studies, *Advanced Management*, Vol. 6, July-September 1941, p. 110.

Actually, this is a relatively candid description of what happens when the industrial engineer "normalizes," levels, rates, pace rates, speed rates or tempo rates the performance of an operator under observation. The time study man compares the observed performance with his *"own concept* of normal performance."

A somewhat less candid description has been offered by Niebel who offers the view that "performance rating is a technique for equitably determining the time required to perform a task by the normal operator after the observed values of the operation under study have been recorded."[1] In this definition we see that use is made of a highly speculative term — equitable — and no mention is made of the fact that the entire process is based on judgment.

It should be said, however, that while Niebel's definition of normalizing leaves much to be desired, his treatment of the subject as a whole is somewhat more revealing.

SPEED, EFFORT AND PACE RATING

Among the other approaches to normalizing is a technique known as "speed" rating. The industrial engineer using this method compares the operator's speed of movement with a concept of normal speed.

Ralph Presgrave has developed a variation of "speed" rating which he calls "effort" rating.[2] The two techniques are essentially identical with the exception that Presgrave recognizes skill as a contributing factor in assessing speed of movement but he does not, as is the case with leveling, segregate the two.

A third variation of the "normalizing" process is known as "pace" rating. This system incorporates most of the ideas underlying speed rating and effort rating with two additions:

(1) It is recognized that all jobs are not performed at the same tempo. So, a variety of concepts of normal is developed for different types of work.

(2) A series of bench marks is provided for different types of work. These bench marks consist of films of key industrial operations.

Dr. Marvin Mundel, while head of the Department of Industrial Engineering at Purdue University, made an effort to develop a rating system which would minimize the area in which subjective rating adjustments must be applied. The system he developed, known as "objective rating," consists of a two step approach to the problem.

First the time study observer *pace rates* observed performance by comparing it with a bench mark against which *all* jobs are evaluated. This bench mark is selected by identifying the simplest task in the shop where the system is to be applied. This task is then recorded on film and time study men refer to it from time to time as a basis for refreshing and reinforcing their concept of normal day work pace.

1. Benjamin W. Niebel, *Motion and Time Study,* 3rd Edition, Richard D. Irwin, Inc., Homewood, Illinois, 1962, p. 265.
2. Ralph Presgrave, *Dynamics of Time Study,* 2nd Edition, McGraw-Hill Book Company, New York, 1945.

During this phase of the procedure, the time study man is concerned with pace alone and nothing else. He does not take into consideration the factors which influence pace such as physical requirements, tolerances and working conditions.

Frequently the filmed version of the bench mark task consists of a multi-image film of the task being performed — at various paces. Thus, the viewer sees on the screen not one picture of the bench mark job but a number of pictures, say twelve.

Having developed the film the industrial engineer must then decide which of the paces portrayed represents "normal" daywork pace. Once this decision is made the time study man then judges all observed performances against the bench mark pace selected from the multi-image film.

The simplest task in the shop is selected as the bench mark because "objective" rating accounts for the factors which affect pace through *secondary adjustments*. There are, all told, six categories of secondary adjustments: (1) amount of body used; (2) foot pedals; (3) bimanualness; (4) eye-hand coordination; (5) handling requirements; and (6) weight.

Under the secondary adjustment for "amount of body used" there are five sub-categories: (A) fingers used loosely; (B) wrist and fingers; (C) elbow, wrist and fingers; (D) arm, etc.; (E) trunk, etc. Similarly, there are sub-categories for each of the other secondary adjustments.

Once the time study observer has pace rated a given job, he then determines the secondary adjustments which apply. Having done so he can compute "normal" time for the job by combining the pace rating and secondary adjustments with the observed time.

Where speed rating is used to "normalize" observed performance, the time study observer simply multiplies the average time for manual elements by his rating factor. Thus, in a case where average observed time came to 1.00 minutes per cycle, piece or process and the observer's rating factor came to 110%, i.e., the operator was judged to be working about ten percent faster than the normal dayworker, the computation would be:

Average observed time × rating factor = normal time

$$1.00'' \times \frac{110\%}{100} = 1.10''$$

If the observer judged that the operator under observation was working at less than daywork pace, he might have rated the performance at 90%. In this case the computation would be:

$$1.00'' \times \frac{90\%}{100} = .90''$$

In the case of "objective" rating the application of secondary adjustments adds a step to the computation. The procedure involved is as follows:

Pace rating × secondary adjustment × average time = normal time

$$\frac{100\%}{100} \times \frac{110\%}{100} \times 1.00'' = 1.10''$$

It is important for trade unionists to be familiar with Mundel's approach to normalizing not because it is widely used in industry (it isn't) and not because he has managed to minimize the element of judgment (he hasn't) but because it helps focus attention on the frailties of this aspect of work measurement.

Mundel has recognized and attempted to come to grips with the fact that it is virtually impossible to rate skill and the fact that effort and pace are not synonomous.

Where other systems require the observer to come up with a composite judgment of an operator's performance, Mundel has made an effort to develop a system which quantifies factors other than pace through basic research.

In this sense Mundel is to be congratulated. Even though industrial engineering practitioners and academicians have spent many an hour searching for verification for their "normalizing" procedures, very little fundamental research has been done.

Unfortunately, Mundel's system leaves so much to be desired that, in the final analysis, it barely raises itself above the rule-of-thumb methods which dominate industrial engineering practices.

To begin with Dr. Mundel's "objective" rating system can only be applied to elements. This means that the time study observer, rather than rating over-all manual performance, rates each element separately. This is justified on the *assumption* that "the total secondary adjustment for an element will be the simple sum of all the appropriate secondary values . . ." In other words it is assumed that there is no interaction, i.e., that what the operator does in performing one element has no relationship with what he does in performing preceding or succeeding elements.

There is no scientific verification for this assumption. As a matter of fact, all available experimental data indicates quite the contrary. For example, Dr. Karl Smith, a University of Wisconsin psychologist, has conducted highly controlled experiments which lend powerful support to the view that there is interaction with respect to the movements involved in performing physical tasks.

There is also some question about the basis for the values assigned to the secondary adjustments. For instance, under the adjustment for "eye-hand coordination" Mundel allows a 2% adjustment when the task requires "moderate vision" and a 4% adjustment when the task requires "constant, but not close" coordination.

This raises several questions: (1) Is this particular quantification supported by acceptable research findings? Harold O. Davidson, in his *Functions and Bases of Time Standards*[1] expresses doubt about the data. (2) Is it possible to differentiate between "moderate vision" and "constant, but not close" in a meaningful way? Or, how does one distinguish between "can be handled roughly" and "only gross control?" (3) Davidson also asks whether the secondary adjustments Mundel has developed have been es-

1. American Institute of Industrial Engineers, Columbus, Ohio, 1957, pp. 44-45.

tablished as independent variables. That is, is it realistic to treat the "amount of body used" and "handling requirements" as independent factors which can be segregated and measured without reference to the influence of one upon the other?

One of the particularly provoking aspects of "normalizing" is the rather widespread tendency of industrial engineers to claim that they are capable of "accurately" judging the performance of a worker in relationship to an arbitrarily established concept of normal performance.

There is a mass of evidence to refute any claim that the term "accurate" should ever be used in connection with normalizing observed performance.

We have one classic example of this evidence in the experiment conducted by Leonard Cohen and Leonard Strauss.[1] These two researchers set out to test the union contention that leveling "does not adequately reflect the actual gain or loss of time by operators working with different degrees of skill and effort."

The experiment consisted of leveling twenty-one completely trained operators for skill and effort. The operation observed involved folding an 18 x 18 inch gauze sheet to a size of approximately 4 x 4 inches. All operators were observed and motion pictures were made of their work.

The observers included Mr. H. B. Maynard and two industrial engineers from his staff.

Thus we see that the experiment encompassed a relatively simple operation, trained workers and expert observers. Even so, the assigned leveling factors would have produced standards which, in terms of ratios, varied from a high of 2.12 to a low of 1! If 1 is assumed to be equal to 100 pieces per hour the standards the three experts set would have varied from 100 pieces an hour to 212 pieces an hour!

Maynard later complained that this enormous variation was caused by the failure of the observers to detect differences in the method employed by the operators. But, if three experts can't detect methods changes in such a simple task, how can more complicated tasks be rated with any more accuracy? And, if "there are as many different methods as there are operators" what good is it going to do if the methods are correctly identified? Which method is the correct method for the normal operator?

Some industrial engineers claim that inexperienced time study analysts may be less capable when it comes to rating but assert that the more experienced man overcomes these defects. Unfortunately, there isn't any more evidence to support this contention than there is to support any other claim relative to rating.

Niebel comments on a survey made by a large manufacturer which disclosed that experienced industrial engineers were not leveling any more accurately than newer men.[2] The S.A.M. has also reported similar findings.

1. L. Cohen and L. Strauss, "Time Study and the Fundamental Nature of Manual Skill," *Journal of Consulting Psychology,* 1946, Vol. 3, pp. 146-153.

2. Benjamin W. Niebel, *Motion and Time Study,* 3rd Edition, Richard D. Irwin, Inc., Homewood, Illinois, 1962, p. 288.

The Cohen and Strauss experiment calls attention to the lack of consistency in rating. There is also statistical evidence that time study men tend to underrate high levels of performance and overrate low levels of performance.[1] This means that an operator whose "true" level of performance is relatively high will, generally speaking, be assigned a lower rating factor than is justified with the result that a standard set using this data would tend to be tight.

This, by the way, is one reason why trade unionists should object to using the best operator as the subject for a time study.

In view of all of the difficulties presented by this phase of work measurement one might ask why industrial engineers don't devise some means of setting standards without normalizing the observed times.

Some firms do make a claim to determining standards based on observed times but, in actuality, normalizing is still involved. It is involved because the company will *select* the operators who are to be studied and they will make time observations only when the operators are performing at a "*normal*" pace. In the final analysis we end up right back where we started.

1. C. J. Anson, "Accuracy of Time Study Rating," *Engineering* 177, March 5, 1954, pp. 301-4.

X . . . JOB ALLOWANCES

The problem of determining job allowances is almost as controversial as normalizing in work measurement, but unfortunately it is not possible to set standards without applying some form of allowances.

Job standards which do not include allowances would be based on the assumption that it is possible to be engaged in productive effort sixty minutes out of each hour for the entire work day. Obviously this is unrealistic.

Aside from the fact that the personal needs of workers must be considered and the fact that fatigue will, in varying degrees, influence performance time and require periods of rest, there are interruptions over which the operator has no control. These include interruptions by supervision, material irregularities, minor tool adjustments and minor machine repairs.

Unfortunately, with but few exceptions, there is no more scientific way of determining the correct personal and rest and unavoidable delay allowances than there is a scientific way to establish normal performance time.

PERSONAL ALLOWANCE

This is illustrated by the fact that, while everyone concedes the need for personal allowances, there is little agreement with respect to the amount of time which should be set aside for this purpose. As a matter of fact, there is wide disagreement over what should be covered by the personal allowance.

Generally speaking the personal allowance is added to "normal" time to provide the worker with an opportunity to make periodic trips to the drinking fountain and rest room. However, in some establishments the personal allowance and rest allowance are combined. In these cases the conditions covered by the allowance are broadened to include working conditions, and the nature of the work to be performed, i.e., repetitive, heavy lifting, works in awkward position, etc.

Niebel reports that "detailed production checks have demonstrated that a 5% allowance for personal time, or approximately 24 minutes in 8 hours, is appropriate for typical shop working conditions."[1] His choice of terms is unfortunate because he leaves the impression that exhaustive study has led to the development of a figure which has some universal characteristic or quality.

It may be that industrial engineers have made exhaustive studies of the problem of quantifying personal allowances, but if they have they have not bothered to report their findings. Even if they had, a great deal of time and effort would have been devoted to a largely impertinent exercise. By definition, the personal allowance is not a universal allowance. It is an allowance which applies to a particular job in a particular location in a particular plant. It is an allowance which should be ascertained on a job-by-job basis.

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1. Benjamin W. Niebel, *Motion and Time Study*, 3rd Edition, Richard D. Irwin, Inc., Homewood, Illinois, 1962, p. 294.

But, this is seldom done. There are very few companies which bother to develop personal allowances for each job standard. Most companies follow the lead suggested by the Niebel quote and apply a flat personal allowance for every job.

The rationale employed by industrial engineers in defending this procedure has a plausible ring to it. For one thing, they say, the jobs in any one plant are similar and normally the workers employed by a company are all exposed to the same general working conditions and plant facilities. And, furthermore, given the highly subjective nature of the personal allowance, why bother going through the motions of establishing an individualized personal allowance for each job standard? We can be just as wrong in estimating an individualized allowance as we can in estimating a flat percentage allowance for all jobs on standard.

The latter is candid but not too helpful and the former misjudges the facts. There is no question that the flat percentage allowance represents the "easy way out" of a difficult problem. But, if a company is going to insist that some form of work measurement is essential in order to remain competitive, then that company ought to be willing to use the best industrial engineering methods available and not be looking for short cuts. Management can't have its cake and eat it too.

The individual requirements of personal allowances are illustrated by the fact that work stations vary in their proximity to drinking fountains and rest rooms. One work station may be in the immediate vicinity of these facilities while another work station may be some distance away. Where a flat personal allowance is applied, other things being equal, the worker some distance away is at a disadvantage.

The availability of these facilities is also a matter of concern, particularly where the universality of the allowance is in question. In one plant there may be a drinking fountain for every 50 workers. In another plant 100 workers may have to share a drinking fountain. In the latter case it may be necessary for a worker to wait in line in order to get a drink.

The same situation may obtain in the case of rest room facilities. In this case one can only conjecture about the potential effect on personal allowance requirements.

REST ALLOWANCE

Rest allowances caused by worker fatigue are even more controversial and more difficult to ascertain. Whereas no one questions the need for the personal allowance, there are a number of writers and numerous practicing industrial engineers who question the justification for a rest allowance.

This isn't to say that there is anyone who denies the presence of fatigue. They simply deny that it has any effect on performance time or claim that they have accounted for fatigue in some other way.

Taylor did not include a rest allowance in his standards. Instead he specified the length and frequency of rest pauses, thereby presumably accounting for any tendency toward reduced output resulting from fatigue.

Merrick used the term "fatigue" as a sort of catch-all to explain the failure of actual rates to equal "optimum" predicted standards.[1]

Gerald Nadler maintains that whenever rest allowances are used it is an "indirect admission that the rating procedure is not accurate or consistent."[2] In his view, pace does not vary with the length of the work day. Where production time increases it is because workers take more time at the end of the day for activities for which allowances are granted.

Mundel also assumes that after a job has been properly rated the operator will be able to meet and exceed the standard throughout the normal work day.

The American Foundrymen's Society, in 1949, collected and published rest allowance data for tasks performed in 54 foundries. Among their objectives was that of setting up a table of "ideal" rest allowances for foundries. In other words, they were acting on the assumption that universal rest allowances can be established. Once again this assumption must be challenged. As Davidson says, an average rest allowance "has no more significance for time study purposes than the average size of men's feet would have to a person ordering a pair of shoes . . . A fatigue allowance is either a proper reflection of the effects of actual conditions prevailing in a particular plant, or it is not, no matter what the average allowance might happen to be over a number of plants."[3]

Much sophisticated scientific knowledge and equipment has been used in conducting physical, chemical and physiological tests aimed at quantifying fatigue. While much important information has been obtained, so far little has been developed for realistic work measurement application.

Various attempts have been made to determine the rest allowance by measuring the decline in production throughout the day. This is based on the assumption that the time lost due to fatigue will increase as the day progresses.

In order to implement this approach the production rate must be measured at various times during the day and either the leveling factor must be held constant or observed performance time must be used as the basis for the computations. If this is not the case, the resulting figures will not reflect the effect of fatigue on performance time because as the rate of observed performance falls off, the leveling factor will, theoretically, also fall off.

For instance, if the observed performance time at the beginning of a work day is 1.00 minutes and the time study man rates the operator at 120%, then the "normal" time will equal 1.20 minutes, i.e., $\frac{100'' \times 120\%}{100} = 1.20''$.

Then, assume that the observed performance time at the end of the

1. D. V. Merrick, *Time Studies as a Basis for Rate Setting,* Engineering Magazine Co., New York, 1919.
2. Gerald Nadler, *Motion and Time Study,* McGraw-Hill Book Co., New York, 1955, p. 471.
3. Harold O. Davidson, *Functions and Bases of Time Standards,* American Institute of Industrial Engineers, Columbus, Ohio, 1957, p. 59.

day is 1.20 minutes. Theoretically, the time study man would level the operator, in this instance, at 100%. Thus, the "normal" time for the operation would be 1.20 minutes $\left(\frac{1.20'' \times 100}{100} = 1.20''\right)$ at the end of the day as well as the beginning. Fatigue would appear, consequently, to have had no effect on the rate.

However, the main problem of fatigue is not how tired a man gets during the work day or how this affects the time in which a part is produced but rather it is how many rest periods of what length are required to prevent the effects of fatigue on heart, lung, muscles, etc. from causing irreparable damage to workers.

In summary it can be said that there is a general recognition of the need to account for personal needs and fatigue in establishing standards, but there is no scientific way to convert these needs into a figure which can be incorporated in a job standard.

They are, therefore, a proper subject of collective bargaining and should be so determined. When industrial engineers assert that they have access to a technique for determining these allowances which yields more objective results, they are abusing the facts. When the industrial engineer claims that he has accounted for fatigue in his rating factor, he should be required to demonstrate precisely how he has done so.

UNAVOIDABLE DELAY ALLOWANCE

In contrast with the personal and rest allowance, measurement of the unavoidable delay allowance (interruption by supervision, variations in material, tool adjustments) is relatively less controversial. Whereas the former are largely concerned with intangibles, the latter is for the most part concerned with interference which can be isolated, identified and measured.

It is one thing to determine how many minutes of each work day should be set aside for the personal needs of the operator and it is another thing to account for the time unavailable for production because of interference beyond the control of the operator.

This is not to say that in actual practice management does a better job of measuring unavoidable delays than personal needs and fatigue. Experience indicates that this is seldom the case. But, the industrial engineer *does* have access to a statistical method, commonly known as work sampling or ratio-delay studies, which elevates measurement of unavoidable delays to a level above that attainable in the case of personal and rest allowances. There is a catch, however. Application of this method requires more time and talent than most companies are either willing or able to allocate.

The unavoidable delay allowance covers interference which can be observed and measured. When a worker is interrupted by his supervisor this can be observed and measured. When material irregularities develop, such as in the case where there is excessive stock on a forging because the dies have begun to wash out or where there has been incomplete removal of risers on castings, this can be observed and measured. Tool adjustments required to maintain quality and size may also be observed and measured.

If it made any sense to conduct continuous time studies throughout a model run or over the entire life of a product, the time study observer would have a complete record of every conceivable kind of unavoidable interference and the determination of the allowance for this purpose would simply involve totaling the time consumed by the operator in unavoidable, nonproductive activity.

Since it wouldn't make sense for a time study observer to time a job throughout its entire production run — the object is to set a standard as quickly as possible — the observer must satisfy himself with a study of a portion of the production run. Accordingly, depending on the type of work under observation, he may elect to study the job for five or ten minutes, for half an hour, for a whole day, several times during the course of a week, and so on.

Generally speaking, the more time he devotes to a study the more likely he is to come up with a standard which represents an adequate reflection of the realities of the job, day in and day out. An unavoidable delay allowance calculated from data accumulated during a relatively short study may not encompass all of the delays the operator will encounter over a period of weeks or months.

A study taken on a job involving the machining of forgings which have been wrought by new dies will not anticipate the increased machining time required as the die washes out. Likewise, observation of the machining of castings which have been thoroughly cleaned will not account for the problems encountered when poorly cleaned castings come through.

For the most part industrial engineers have been content with measurement of unavoidable delays as an integral part of the time study. This has meant that interference occurring during the course of the time study has served as the major source of information. In some instances the information thus derived proves to be satisfactory; in others it is unsatisfactory. Whether it is or isn't is largely dependent on luck.

Work sampling, on the other hand, provides a means of determining the unavoidable delay allowance which is independent of the time study itself and which employs a statistical technique endowed with more objectivity and reliability than most phases of time study.

When employing this method the time study man makes a large number of *random* observations of the job. Each time he observes the job he records information which indicates whether the operator was working or not working. If the operator was not working the time study man describes what he was doing. He does not time the operation during a work sampling study. Upon completion of his random observations the time study man divides the number of recordings of unavoidable delays by the number of recordings of work. This gives the percentage allowance which should be applied in computing the standard. And, the allowance has been derived in a completely impersonal way, without the use of the stopwatch.

MACHINE ALLOWANCE

In some cases a machine allowance is added to the three allowances discussed in previous sections. This is particularly true where the jobs on incentive vary from those which are almost entirely "man-paced" to those which are almost entirely "machine-paced."

If the wage incentive system calls for standards which offer earnings opportunity for the average worker equal to 125% or 130% of his incentive base rate, the worker assigned to a job which is largely machine-paced will have difficulty attaining expected earnings.

The problem involved can be illustrated as follows:

(1) First take the example of a job which is 75% man-paced and 25% machine paced. If the total time per cycle (or per piece) is 2.00 minutes then the manual time in the cycle is equal to 1.50 minutes (75% of 2.00″ = 1.50″) and the machine time is equal to .50 minutes.

In order to attain earnings equal to 125% of his incentive base rate the operator will have to produce each piece or complete each cycle in 1.60 minutes. Since machine time is fixed he will have to achieve all of the .40 minutes reduction in cycle time during the manual portion of the cycle. Thus, it will be necessary for him to work at a pace during manual time which will enable him to reduce manual time from the 1.50 minutes provided in the standard to 1.10 minutes (1.50″ − .40″ = 1.10″). In order to do this he will have to work at 136.5% of "normal" daywork pace. As can now be seen, the operator must work at 136.5% of "normal" pace during the manual portions of the cycle in order to achieve average earnings equal to 125% of his incentive base rate.

(2) Now, let's reverse the example and discuss a standard which consists of 25% manual time and 75% machine time. Assuming a cycle time of 2.00 minutes per piece we now have a standard calling for .50 minutes manual time and 1.50 minutes machine time. Where expected attainment is once again equal to 125% of the incentive base rate it will, once again, be necessary for the operator to reduce the cycle time from 2.00 minutes to 1.60 minutes to achieve this goal. But, this time the entire reduction must come from the .50 minutes manual time, not 1.50 minutes as in the previous example. He will have to reduce manual time, through increased effort, from .50 minutes to .10 minutes. This would require the operator to work at 500% of the "normal" daywork pace, a rate which is patently impossible.

Because of this it is necessary to include a machine allowance so that earnings opportunity from one job to the next will be as equal as possible. By adding a machine allowance to the machine-paced portion of the cycle in our second example, it will be possible for the operator on this job to equal the expected attainment of 125% whereas without it he could not.

Actually there is no completely satisfactory answer to the problem of equivalent earnings opportunity where there are varying proportions of machine and man paced activity. This is a fact which can be illustrated by citing an example similar to the two above with the exception that a machine allowance equivalent to expected attainment is included in the standard.

(1) In our first example above we assumed a standard consisting of 1.50 minutes manual time and .50 minutes machine time, giving a total time per piece of 2.00 minutes. If a machine allowance equal to our assumed expected attainment is added, the total time becomes 2.125 minutes per piece. This figure is derived by adding 25% of machine time, i.e., .125 minutes to the cycle. Now, if the operator works at 125% of the "normal" daywork pace during the manual portion of the cycle he will average 125% throughout the entire cycle. This can be illustrated as follows:

If the operator performs at 125% of "normal" daywork pace during the manual portion of the cycle he will complete the manual elements in 1.20 minutes. Add the *actual* machine time (.50 minutes) to manual time at the 125% effort level and we get a total elapsed time for the cycle of 1.70 minutes. Since the normal time per piece including the machine allowance is 2.125 minutes we can readily see that the operator has averaged 125% of "normal" throughout the cycle ($2.125 \div 125\% \times 100 = 1.70''$).

Now, let's assume that the operator did not perform at an incentive pace during the manual portion of the cycle. In that case the total actual elapsed time would be 2.00 minutes against a standard of 2.125 minutes and the operator's earnings would approximate 106% of his incentive base rate.

(2) Our second example involved a job where the manual time came to .50 minutes and machine time came to 1.50 minutes. Adding the machine allowance we get a total time per cycle of 2.375 minutes ($1.50 \times \frac{125}{100} + .50 = 2.375''$). If the operator applies himself at an effort level equivalent to 125% of the "normal" daywork rate he will average, as was true above, 125% of his incentive base rate.

However, if he performs at "normal" daywork pace his earnings level will equal between 118 and 119% of his incentive base rate. Thus, while applying no incentive effort at all he can exceed his base rate by 118 to 119% in contrast with the operator in (1) above who would exceed his base rate by about 106%.

It becomes clear, therefore, that in the process of eliminating one inequity another may be created.

There are other allowances which show up in various systems from time to time, but generally speaking they are designed to cover a problem illustrated by the allowances discussed in preceding paragraphs.

Our next problem will be to deal with the actual application of the allowances once they have been determined. Here we will find that a great many industrial engineers are committing inexcusable errors.

APPLICATION OF ALLOWANCES

The actual arithmetic involved in applying allowances to a work standard is, strange as it may seem, almost as controversial as the determination of the allowances. This is true in the case of personal, rest and unavoidable delay allowances as well as in the case of the machine allowance.

A description of the most widely practiced method of applying allowances will indicate why this is so.

As previously indicated, the industrial engineer must determine the number of minutes of each day which must be set aside for personal needs, for recovery from the effects of fatigue and for interruptions beyond the control of the operator. The time involved will vary from job to job.

For illustrative purposes we will assume that the personal allowance is set at 3 minutes an hour or 24 minutes a day, that the rest allowance is also set at 3 minutes an hour and that the unavoidable delay allowance is, likewise, set at 3 minutes an hour.

This means that 9 minutes of each hour or 72 minutes out of each 8 hours will be unavailable for production.

Then, the industrial engineer converts the allowances from minutes to a percentage. This is accomplished by dividing 72 minutes by 480 minutes (the number of minutes in an 8 hour day). The answer is 15%. That is, 72 minutes is equal to 15% of 480 minutes.

Having converted the allowances into percentages the time study man proceeds to compute the allowed time or standard time by applying the percent allowance to normal time.

Normal time, the reader will recall, is equal to observed cycle time after it has been "normalized." Thus, if observed cycle time on a job came to 1.50 minutes per piece and the time study man's rating factor equalled 115%, normal time per piece would equal 1.725 minutes per piece, i.e., $1.50 \times \frac{115}{100} = 1.725$ minutes.

Following the most widely practiced method of applying allowances the time study man would multiply 1.725 minutes by 15% and add the result to 1.725 minutes to derive allowed or standard time.

The arithmetic works out as follows:

$1.725'' \times .15 = .259$

$1.725'' + .259 = 1.984$

$1.984'' =$ allowed time per piece

This method is in error.

It is in error because it is arithmetically incorrect to express allowances as a percent of the total day and then apply them to effective or actual working time. An article in a management publication puts the issue as follows:

"In essence, the principal fallacy in the usual method of making allowances . . . is that since the effective or actual working time is always less than the total working day, a percent, computed on the total working day, and then applied to a much smaller part of the total working day, namely the effective or actual working time, is no longer equivalent to the number of minutes of allowance originally intended."[1]

The point the authors of this quotation are making can be illustrated by computing the aforementioned allowances as a percent of effective working time in a day. If the method commonly in use is arithmetically correct, then effective working time in a day plus allowances should add up to 480 minutes or 8 hours. It doesn't.

Using 72 minutes as the total of personal, rest and unavoidable delay allowances in a day, we find that the effective working day equals 408 minutes. Fifteen percent of 408 equals 61.2, i.e., $408 \times .15 = 61.2$ minutes. Adding the allowances thus derived to the effective time, we get a total of 469.2 minutes. But we know that the total should be 480. This method has, therefore, resulted in an understatement of the allowances of 10.8 minutes.

The point can be further illustrated by calling attention to the different production standards which result from the incorrect as against a correct method of applying allowances.

Several paragraphs back we spoke of a situation in which the normal time per piece equalled 1.725 minutes. Daily production at standard pace would be obtained by dividing effective time by the normal time. With effective time equal to 408 minutes ($480 - 72 = 408$) and time per piece equal to 1.725 minutes, daily standard production equals 236.58 pieces.

However, if the allowances are added to normal time per piece, continuing with the previous example, ($1.725 \times .15 + 1.725 = 1.984$) and the total minutes in a day are divided by allowed time, we get a different result.

$480 \div 1.984 = 241.9$ pieces per day

Thus we see very clearly that the incorrect method of applying allowances has the effect of increasing the work load.

In addition to the arithmetic error involved in applying allowances to normal time after having converted them from minutes to a percentage figure there is another equally good reason for abandoning this practice. Workers who are required to produce against a standard ought to be fully aware of the amount of time provided for allowances. A standard which expresses allowances in terms of percentages is obscure. When a worker is told that allowed time or standard time is 1.984 minutes per piece, how is he to figure just what his allowances are in meaningful terms? It doesn't help much to say that the allowances come to 15%.

On the other hand, allowances expressed as minutes per hour or day are quite easy to understand. A worker who knows that he has nine or ten minutes an hour available for allowances can keep track of the availability of allowance time more readily than when the allowances are stated in an obscure form.

In those instances where there is a compelling reason to express allowances in percentage terms rather than in minutes per hour or day, there is

1. David Anderson and Arthur H. Hansen, "The Right and Wrong of Time Study Computations," *The Iron Age,* August 17, 1944, p. 61.

a way of doing so which is arithmetically correct. Ralph Barnes proposes one method in his *Motion and Time Study.*[1]

$$\text{Standard time} = \text{normal time} \times \left(\frac{100}{100 - \text{allowance in } \%}\right)$$

Using the example we have been working with and substituting accordingly, the arithmetic involved is as follows:

$$\begin{aligned} \text{Standard time} &= 1.725 \times \left(\frac{100}{100 - 15}\right) \\ &= 1.725 \times \frac{100}{85} \\ &= 1.725 \times 1.176 \\ \text{Standard time} &= 2.029 \end{aligned}$$

Note that the standard time by the Barnes method is 2.029 in contrast with a standard time of 1.984 under the incorrect method. Note also that standard output per day is equal to 236.6 pieces $\left(\frac{480''}{2.029''}\right)$, a figure which is obtained when allowances are expressed in minutes.

APPLICATION OF MACHINE ALLOWANCES

Another arithmetic problem arises occasionally in connection with application of the machine allowance. Frequently union representatives run into the argument that personal, rest and unavoidable delay allowances should be computed and added to machine time and then the machine allowance should be computed, as a percent of machine time, and added to the machine time plus other allowances.

Company representatives argue that applying the machine allowance as a percent of machine time plus allowances is pyramiding. However, this is not the case. When both the machine allowance and other allowances are computed as a percent of normal time the operator is, in effect, required to take his allowance at an incentive pace.

The problem can be illustrated by first working out an example which assumes that all time is manual and then working out an example which assumes that all time is machine time.

Beginning with the example of a job which is composed in its entirety of manual time and assuming normal cycle time equal to 2.00 minutes and allowances equal to 48 minutes per day, or 10%, the following computations will lead to determination of the standard in terms of pieces per hour.

(1) $2.00'' =$ normal cycle time (manual)

(2) $10\% =$ allowances (personal, rest, unavoidable delay)

(3) $$\begin{aligned} \text{standard} &= 2.00 \times \left(\frac{100}{100 - 10}\right) \\ \text{“} \quad &= 2.00 \times \frac{100}{90} \\ \text{“} \quad &= 2.22'' \text{ per piece} \end{aligned}$$

1. Ralph M. Barnes, *Motion and Time Study,* 3rd Edition, John Wiley & Sons, Inc., 1949, pp. 374-375.

(4) Pieces per hour $= \frac{60}{2.22}$

" $= 27$

(5) At 125% of normal pace the standard number of pieces per hour of output will equal 33.75 pieces, i.e., $27 \times \frac{125}{100} = 33.75$

We see from this example that it is possible for the operator to exceed the standard by applying extra effort over and above day work effort. However, where the cycle is wholly or partially machine controlled the operator's opportunity to exceed the standard is limited. Therefore a machine incentive allowance is often applied.

Turning now to the example of a job which consists entirely of machine time, we begin with the same computations.

(1) 2.00″ = normal cycle time (machine)

(2) 10% = allowances (personal, rest, unavoidable delay)

(3) standard $= 2.00 \times \left(\frac{100}{100 - 10}\right)$

" $= 2.00 \times \frac{100}{90}$

" $= 2.22''$ per piece

(4) Pieces per hour $= \frac{60}{2.22}$

" $= 27$

(5) in this example it is not possible for an operator to achieve incentive earnings because the entire cycle is machine controlled, i.e., increased effort on the operator's part will not result in increased output.

(6) therefore, if the base rate for the job is to be exceeded, a machine allowance must be applied.

(7) the machine allowance can be applied in two ways (assume a machine allowance of 25%)

(a) normal time × machine allowance *plus* normal time × allowances
or

(b) normal time × machine allowance × allowances

(8) following the first alternative and substituting as per our example we get

(a) $2.00 \times .25 + 2.00 \times \frac{100}{90}$ = standard time per piece

(b) $.50 + 2.22 = 2.72$

(c) $\frac{60}{2.72}$ = pieces per hour at standard

(d) 22 = pieces per hour at standard

(e) $22 \times \frac{125}{100}$ = pieces per hour at 125% of standard

(f) 27.5 = pieces per hour at 125% of standard

(9) following the second alternative and substituting accordingly we get:

(a) $2.00 \times \frac{125}{100} \times \frac{100}{90} = 2.78$

(b) $\frac{60}{2.78}$ = pieces per hour at standard

(c) 21.6 = pieces per hour at standard

(d) $21.6 \times \frac{125}{100}$ = pieces per hour at 125% of standard

(e) 27 = pieces per hour at 125% of standard

By the first method the number of pieces per hour required to exceed the standard by 25% is 27.5 and by the second method it is 27. This clearly demonstrates the error of the first method since, by definition, production during effective time can not exceed 27 pieces. Effective time, where the allowances are equal to 10%, is 54 minutes per hour. In our example the cycle time per piece is 2.00 minutes, which means that the machine will produce 27 pieces during effective production time, i.e., $\frac{54}{2.00} = 27$.

The charge that the second method of combining machine allowances and personal, rest and unavoidable delay allowances leads to pyramiding is without foundation. It is the first method which is in error.

XI . . . REPRESENTATIVE TIME

Once the time study man has completed his observations he is faced with the problem of deciding which of the times he has recorded is to be selected as the representative time. This is the case because his time study work sheet will indicate that the operator took different lengths of time to perform the same work sequence.

Work sheet No. 7 provides an example of what a time study work sheet might look like where the observer timed 10 cycles of an operation consisting of three elements.

As the example stands, a question arises with respect to which of the elapsed times recorded for Element No. 1 is representative? .08 minutes? .09 minutes? .10 minutes?

The same question arises in the case of elements No. 2 and No. 3.

Some time study men use their own best judgment. After examining the data, they select a time which they believe is representative of the element.

Others strike the "abnormally high" and the "abnormally low" recordings from the study and then compute an average.

Then there are still others who use one of the three common measures of central tendency, i.e., the mode, the median and the average.

We would reject the first of these methods because experience has taught us that when the time study man uses his own judgment in selecting representative time, he quite frequently chooses a time which is on the low side. We might also add that where an arithmetic procedure is available it ought to be used.

The practice of striking-out low and high times is highly questionable, particularly where no effort has been made to diagnose the cause of the "abnormal" recordings.

The simplest measurement is the *mode* which is merely the value in a series which occurs most frequently. In our example the mode for Element No. 1 would be .08 minutes; the mode for Element No. 2 would be .40 minutes; and, the mode for Element No. 3 would be .07 minutes.

A second relatively simple measurement is called the *median.* The median is defined as the middle value, or the value which is exceeded by as many values as it exceeds. This figure is obtained by listing the elapsed time for each element in order, from the lowest values to the highest values, repeating each value as often as it occurs in the study. Our example would be set-up as follows for this purpose:

TIME STUDY OBSERVATION

DATE ______
TIME START ______ A.M. P.M.
TIME STOP ______ A.M. P.M.
ELAPSED TIME ______
NUMB. PIECES ______

SHEET NO. ______
NO. SHEETS ______

NUMBER / NOTES	Line	ELEMENTS (1) PICK-UP, LOAD, LOCK, START MACHINE T	(1) R	(2) DRILL ½" THROUGH, FEED KICKS OUT T	(2) R	(3) UNLOCK, UNLOAD, LAY ASIDE, REACH T	(3) R
	1	08	.08	40	.48	07	.55
	2	09	.64	39	1.03	06	.09
	3	10	.19	41	.60	07	.67
	4	08	.75	40	2.15	07	.22
	5	09	.31	41	.72	06	.78
	6	08	.86	40	3.26	07	.33
	7	09	.42	39	.81	06	.87
	8	08	.95	40	4.35	07	.42
	9	09	.51	40	.91	06	.97
	10	08	5.05	41	.46	08	.54
	11						
	12						
	13						
	14						
	15						
	16						

SUMMARY

	(1)	(2)	(3)
Total Time			
No. of Readings			
Av. of Readings			
Frequency			
Average Time			
El. Rating Factor			
El. Normal Time			

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A			
B			
C			
D			
E			
F			
G			
H			
I			

Av. Cycle Time ______
Cycle Rating Factor ______
Normal Cycle Time ______

Percent Allowances

Pers.	Fat.	Delay	Total

Std. Time Per Unit ______
Pieces Per Hour ______
Std. Hours Per 100 ______

Allowances in Minutes

Pers.	Fat.	Delay	Total

Avail. Prod. Min. Per Hr. ______
Pieces Per Hour ______
Std. Hrs. Per 100 ______

Work Sheet No. 7

Element No. 1	Element No. 2	Element No. 3
.08	.39	.06
.08	.39	.06
.08	.40	.06
.08	.40	.06
.08	.40	.07
.09	.40	.07
.09	.40	.07
.09	.41	.07
.09	.41	.07
.10	.41	.08

The middle most point for Element No. 1 lies halfway between .08 minutes and .09 minutes so that the median would equal .085 minutes. Following the same procedure for Elements No. 2 and No. 3 we get .40 minutes and .07 minutes, respectively.

The third measure of central tendency and the measure most commonly used is the arithmetic mean or average. The process involved is one which is familiar to almost everyone because sometime almost everyone has had occasion to compute an average by the arithmetic mean process. This process requires us to total the value of the elapsed times for each element and divide by the number of recordings.

Again referring to our previous example we first get totals for each element:

	Element No. 1		Element No. 2		Element No. 3
	.08		.40		.07
	.09		.39		.06
	.10		.41		.07
	.08		.40		.07
	.09		.41		.06
	.08		.40		.07
	.09		.39		.06
	.08		.40		.07
	.09		.40		.06
	.08		.41		.08
	—		—		—
Total	.86	Total	4.01	Total	.67

Having obtained totals for each element we now divide the total by the number of recordings — 10 in our example — to obtain the arithmetic mean.

Element No. 1 $\quad .86 \div 10 = .086$
Element No. 2 $\quad 4.01 \div 10 = .401$
Element No. 3 $\quad .67 \div 10 = .067$

Under normal circumstances the arithmetic mean is the most acceptable expression of representative time. It is the only measure of central tendency which gives equal weight to all recorded time values. The mode may or may not reflect the average satisfactorily, depending on the distribution of recorded values. It is conceivable, for instance, that the most frequent value recorded may be less than the arithmetic mean or it may be more than the arithmetic mean. This is also true of the median.

The arithmetic mean itself is subject to some severe limitations. In those instances where the data does not conform to the shape of the normal curve, i.e., the data is skewed, the average may not provide a meaningful measure of representative time. Therefore, even though the arithmetic mean is recommended as the most desirable measure of central tendency — and in the greatest majority of cases it remains the most satisfactory measure to use in time study work — it should not be used in an uncritical fashion.

XII . . . COMPUTING A STANDARD

Now the time study observer is ready to compute a standard.

His first step after having completed his observations and having recorded his rating factor, is to perform the arithmetic required to convert his continuous stopwatch readings into elapsed times for each element. This process involves nothing more than simple subtraction.

The preceding section dealing with determination of representative time illustrates what is involved. However, in order to assure understanding of the steps required we will repeat the process, step by step.[1]

First, the observer's continuous stop watch recordings:

Element No. 1	Element No. 2	Element No. 3
Pick-up, load, lock, start machine	Drill ½″ through, feed kicks out	Unlock, unload, lay aside, reach
.08	.48	.55
.64	^{1}.03	.09
.19	.60	.67
.75	^{2}.15	.22
.31	.72	.78
.86	^{3}.26	.33
.42	.81	.87
.95	^{4}.35	.42
.51	.91	.97
^{5}.05	.46	.54

Reading from left to right and down we see that the first stop watch reading came .08 minutes after the study started. The second reading came .48 minutes after the study started, the third came .55 minutes after, the fourth came .64 after, and so on.

Now the observer must convert his continuous readings into elapsed times:

Element No. 1		Element No. 2		Element No. 3	
.08	.08	.40	.48	.07	.55
.09	.64	.39	^{1}.03	.06	.09
.10	.19	.41	.60	.07	.67
.08	.75	.40	^{2}.15	.07	.22
.09	.31	.41	.72	.06	.78
.08	.86	.40	^{3}.26	.07	.33
.09	.42	.39	.81	.06	.87
.08	.95	.40	^{4}.35	.07	.42
.09	.51	.40	.91	.06	.97
.08	^{5}.05	.41	.46	.08	.54

The underlined figures — they are the elapsed times — were obtained by subtraction. For example: .08 − .00 = .08; .48 − .08 = .40; .55 − .48 = .07; .64 − .55 = .09.

1. The computations which appear on the following pages are recorded on work sheets in the Appendix.

Next, the elapsed times for each element are totaled:

	Element No. 1	Element No. 2	Element No. 3
	.08	.40	.07
	.09	.39	.06
	.10	.41	.07
	.08	.40	.07
	.09	.41	.06
	.08	.40	.07
	.09	.39	.06
	.08	.40	.07
	.09	.40	.06
	.08	.41	.08
	—	—	—
Total	.86	4.01	.67

Having totaled the elapsed elemental times, the observer is now ready to derive representative time. Using the measure of central tendency known as the arithmetic mean or average, we proceed as follows:

Element No. 1	Element No. 2	Element No. 3
$\frac{.86}{10} = .086$	$\frac{4.01}{10} = .401$	$\frac{.67}{10} = .067$

If all the elements are cyclical, as in the case of our example, no further averaging computations are required. However, if there is a non-cyclical element, such as inspection, another step is required. Suppose, for instance, that instead of the three elements making up our example there was a fourth element which called for inspection of the finished piece every five pieces. Suppose further that during the course of the study the observer timed the inspection element twice, recording elapsed times of .33 and .38 minutes.

Representative time would be determined in the same fashion as above. i.e., $\frac{.33 + .38}{2} = .355$. However, this figure as it is cannot be incorporated in the standard. It must be pro-rated. This is accomplished by dividing the average time for inspection, .355, by the frequency of occurrence of the inspection element. Since inspection is required every 5 pieces, the frequency of occurrence is 1 in 5. Therefore, .355 ÷ 5 gives us the pro-rated share of the inspection element which can be attached to the time per piece.

	Element No. 1	Element No. 2	Element No. 3	Element No. 4
Average of the Readings	.086	.401	.067	.355
Frequency	1/1	1/1	1/1	1/5
Average	.086	.401	.067	.071

The time study man will have rated, or normalized, the manual elements either as one or separately. If we assume that he rated the manual elements separately and assigned a rating of 115% for Element No. 1, 110% for

Element No. 3 and 90% for the inspection element he must "normalize" the average times by multiplying the average (arithmetic mean) by the rating factor.

	Element No. 1	Element No. 2	Element No. 3	Element No. 4
Average of the Readings	.086	.401	.067	.355
Frequency	1/1	1/1	1/1	1/5
Average	.086	.401	.067	.071
Rating Factor	115	—	110	90
Normal Time	.0989	.401	.0737	.0639

The normal time per piece equals the total of the normal elemental times for each of the four elements.

$$\begin{array}{r} .0989 \\ .4010 \\ .0737 \\ .0639 \\ \hline .6375 \end{array} = \text{normal time/piece}$$

Quite frequently the figure derived for normal time/piece will be rounded at this point since a figure consisting of four digits to the right of the decimal point tends to exaggerate the accuracy of the process employed in arriving at the figure. In other words, considering the degree to which judgment enters into the process at each step, there is no basis for a four decimal answer. The rounded figure in this case would equal .64 minutes per piece at normal, daywork pace.

Now we are ready to convert the normal time per piece into pieces per hour, standard hours per 100 pieces, price per piece or any other form of expression which may be employed under a particular system.

Pieces per hour may be derived in one of two ways. Where the allowances are expressed in minutes we simply divide the normal time per piece into the effective production time. Assuming allowances of 9 minutes per hour the standard in pieces per hour equals: $51 \div .64 = 79.7$.

If allowances are expressed in percentage terms then, using the proper method as explained by Barnes, pieces per hour would be computed as follows:

$$\frac{60}{.64\left(\dfrac{100}{100 - \text{allowances}}\right)} = \text{pieces per hour}$$

$$\frac{60}{.64 \times \dfrac{100}{85}} =$$

$$\frac{60}{.753} = 79.7 \text{ pieces per hour}$$

Standard hours per 100 pieces is derived by the following procedure where allowances are expressed in minutes:

$$\frac{\text{normal time/piece} \times 100}{\text{effective production time}}$$

$$\frac{.64 \times 100}{51} = 1.24 \text{ hours/hundred pieces}$$

Where allowances are expressed in percentages the formula is:

$$\frac{\text{allowed time/piece} \times 100}{60}$$

$$\text{allowed time} = .64 \left(\frac{100}{100 - \text{allowances}}\right)$$

$$= .64 \left(\frac{100}{100 - 15}\right) = .64 \times \frac{100}{85}$$

$$.753 =$$

$$\frac{.753 \times 100}{60} = 1.24 \text{ hours/hundred pieces}$$

The *price per piece* is figured by dividing the base rate or timing rate by the standard number of pieces per hour. Where the base rate is \$2.00 an hour and the required pieces per hour is 79.7, the price per piece equals approximately 2.5 cents.

The price per 100 pieces equals the base rate divided by pieces per hour times 100:

$$\frac{\$2.00}{79.7} \times 100 = \$2.50$$

XIII . . . STANDARD DATA

Up to this point we have dealt only with the stopwatch time study approach to establishing work standards. Now we will turn our attention to alternative procedures which are currently in vogue.

The alternatives are variously referred to as standard data, elemental standard data, predetermined motion time systems and synthetic basic motion times.

These systems all have several features in common, the most notable being that the stopwatch is either wholly or partially done away with.

Actually, while various forms of standard data are occupying the limelight in industrial engineering circles today,[1] standard data is neither newly arrived nor predominate.

We can go back as far as Frederick Taylor — sometimes referred to as the "father" of time study — to discover interest in the development of work measurement procedures which minimize the use of the stopwatch. Taylor, in his paper on "Scientific Management" envisaged the day when a sufficient volume of basic data would be available to make further stopwatch studies unnecessary.

As early as 1924, A. B. Segur developed data from analysis of micromotion films which led him to the conclusion that if the same basic motion is performed by different operators employing the same motion pattern, the time involved is relatively constant. Then, in 1938, the Work Factor Company, Inc. came forward with motion-time values gathered by the micro-motion technique, stopwatch studies and other means.

Methods-Time Measurement data commonly known as MTM, was published in 1948 and Basic Motion Timestudy was developed by Ralph Presgrave and his associates during the 1945-1951 period. A number of other standard data systems also emerged in the immediate post World War II period.

Thus, we can see that the alternatives to direct stopwatch time studies have been used by industrial engineers for a number of years dating back, in fact, to the years when formalized work measurement was in its infancy.

In addition to having been around for some time, we can also say that, in spite of the amount of print being devoted to various standard data systems, actual application in industry is relatively limited. One survey suggests that about one-third of the firms which have a formalized work measurement system are making use of some form of standard data. Even this figure must be interpreted because stopwatch time studies are also used by these companies which means that even though standard data is used, it is not used exclusively.

TWO FORMS OF STANDARD DATA

Generally speaking, standard data can be divided into two broad categories, i.e., on the one hand there is the variety which attempts to measure

1. *Factory,* September 1963, pp. 123-128.

elements of work and on the other hand there is the variety which attempts to measure basic human motions.

The "work elements" school formulates its data in terms of groupings of motions which reoccur in a number of different operations. This approach to work measurement is often described as standard data or elemental standard data.

In contrast the "human motions" school formulates its data in terms of basic motions or therbligs.

The phrase predetermined motion time system or synthetic motion time system is generally used when referring to this type of work measurement data.

The distinction between the work element and the human motion schools can be illustrated by indicating that standard times for the former would be developed for a group of work elements such as pickup, load, lock and start machine, while standard times for the latter are developed for what are presumed to be basic body motions such as grasp, reach, move, hold, release and position.

WHY STANDARD DATA?

From management's point of view there are several reasons why a standard data system may be preferable to a stopwatch system.

Some companies are required to estimate the cost of new work in order to be able to bid for jobs which other companies are contracting out. Where standard data is available, the company has a tool to use in estimating direct labor cost before the job ever reaches the shop floor.

A second advantage claimed for standard data is speed and economy, i.e., industrial engineers are supposed to be able to establish standards by this method much more quickly than by the stopwatch method.

A third advantage attributed to standard data is consistency. Proponents argue that stopwatch time studies which require rating of operator performance frequently yield inconsistent earnings opportunity because of the frailties of rating. Standard data is claimed to overcome this difficulty by eliminating rating as one of the steps involved in setting a standard. The reader should note, however, that rating is still an integral part of the process. This is true because in the process of developing standard data which will subsequently be used to set standards, the authors of a given system were required to performance rate the observed times recorded by stopwatch, kymograph, motion picture camera or what have you.

COMMON CHARACTERISTICS

While there may be some exceptions to the rule, generally speaking it can be said that all forms of standard data have several common characteristics.

To begin with, all systems originate in "stopwatch" time studies or their equivalent. This means that all of the judgments required to produce a work standard by the stopwatch method are, in one way or another, present in standard data.

Secondly, as mentioned above, even though rating is eliminated from the work measurement process at the time a standard is actually established, the data itself was rated during its developmental stage.

Third, the standard data method assumes that there is such a thing as "standard" elements or basic motions which can be identified, measured and applied universally.

Fourth, to one degree or another, standard data systems assume that work elements and/or basic motions are independent of each other. There is an assumption that once data is developed for an element or basic motion, that data will prove to be valid even though the motion may occur in a different sequence every time it is repeated.

Fifth, proponents argue that standard data is superior to stopwatch time studies because even though errors of judgment may have been made in developing the data, these errors will have been averaged out by the device of combining masses of information.

DISTINCTIONS

On the other hand there are some significant distinctions which must be noted.

In the first place, work elements systems are largely derived from stopwatch established elemental standard data while the human motions systems are based on measurement of basic motions and are commonly referred to as predetermined motion time systems.

Elemental standard data, as previously indicated, involves the determination of normal performance times for groups of motions which are presumed to be repeated in the performance of a variety of industrial tasks. Thus, analysis of numerous stopwatch time studies may lead the time study man to the conclusion that he can distill out of these studies a "universal" standard performance time for such elements as "pick-up small casting and load in fixture," or "remove piece from fixture and lay aside."

Predetermined motion time systems, in contrast, involve the determination of "universal" normal times for basic motions — often called therbligs — which are presumed to be irreducible.

The Work Factor System, for instance, is built around eight basic motions or work elements. The eight are: transport, grasp, preposition, assemble, use, disassemble, mental process and release.

Methods-Time Measurement data was developed for similar basic motions. MTM data, which is published in the form of a small folder, includes tables for reach, move, turn and apply pressure, grasp, position, release, disengage, eye travel time and eye focus, body, leg and foot motions and simultaneous motions.

It is probably obvious to the reader that ordinary stopwatch time studies play a minor role in determining predetermined motion time data. Measurement of basic motions by stopwatch is difficult if not impossible. Because of this, the authors of these systems have relied heavily on frame by frame analysis of motion picture films.

In spite of these rather pronounced distinctions, it must be noted that the similarities between stopwatch derived elemental standard data and predetermined motion time systems are greater than the differences.

Both systems require measurement. The measuring instrument or procedure may vary, but the problems inherent in each system are essentially the same. What should the industrial engineer measure? Under what circumstances and conditions should measurement be attempted? To what extent must the procedure, equipment, material and work place be standardized? In other words, the questions which must be raised and answered in connection with ordinary stopwatch time studies must also be raised and answered where development of elemental standard data and predetermined motion time data is at issue.

It can also be observed — to repeat a point which must be stressed — that both the "work elements" and "human motions" forms of standard data required rating. MTM data, for example, was leveled by the Westinghouse technique.

The common ancestry which standard data systems share is emphasized at this point because proponents are inclined to assert that standards set by standard data are superior to those set by stopwatch time studies. Aside from the fact that there are several serious defects in the underlying assumptions of standard data, it is difficult to understand how standard data can rise above the weaknesses of its origin.

BASIC ASSUMPTIONS CHALLENGED

There are several basic assumptions underlying standard data which require analysis.

Standard data requires the determination of a single time value for each basic movement or standard element. In order for a figure of this sort to have meaning we must assume that it is possible to define basic motions and elements which are unique, i.e., they cannot be reduced to lesser motions and elements which vary in performance time among themselves.

Certainly elemental standard data does not meet this test. Harold O. Davidson draws a comparison between simplified MTM data and detailed MTM data which illustrates this point:

"Among the elements of the 'simplified' data is a Type I Reach, or Move, with distance as a variable to which the 'Standard' time is related. Quite obviously there are many sub-classes within this element, and the authors of the system are fully aware of this. In their 'complete' data they establish Reach and Move as two separate classes, introducing five different 'cases' for the former and three different 'cases,' plus a weight factor, for the latter. Now our question is: Does the element, Type I Reach or Move, meet our practical criterion for a unique element? Assuming, for the moment only, that the values assigned to the sub-classes in the 'complete' data are reasonably correct, we note that the values for a 10 (inch) movement vary from .00522 minutes to .01014 minutes. The 'simplified' data allow the single value of .00835 for 10 (inch) movements of all sub-classes (the value obtained from the author's table was multiplied by 100/115, since the 'simplified' data include a 15% allowance). Computation shows that a discrepancy as great as plus 60% or minus 18% may be introduced in the case of this element by the use of the 'simplified' table instead of the 'complete' data. This is certainly a significant difference, and so the 'simplified' data would not appear to meet the practical criterion of unique elements for many purposes."[1]

Davidson goes on to question even the uniqueness of the "complete" data, calling attention to a study in which it was demonstrated that the time for positioning varies significantly according to the way in which a part is held.[2] And yet, complete MTM data does not acknowledge this fact. Time values for the element Position are determined, when using MTM data, according to ease of handling, class of fit and degree of symmetry.

There is also evidence to support the conclusion that the time required to perform basic motions is influenced by the direction of the motion, in the case of arm movements, and other subtle but critical relationships involving motor activities. For example, predetermined motion time systems allow the same time for lifting and lowering a weight as walking up and down a flight of stairs.

The establishment of a single time value for each basic movement or standard element, in addition to resting on the assumption that it is possible to identify and measure unique motions or combinations of motions, also assumes that the single time value possesses universality.

When time values are developed by stopwatch time study and a standard is established, the resulting data is applied to one job and one job only. No attempt is made to use this data for the purpose of setting standards on other similar jobs. However, this is not true of standard data.

Wherever the element "pick up small casting and place in fixture" is found or wherever the basic motions, e.g., move, reach, grasp and position are found, it is assumed that the single standard data time value applies.

The validity of this assumption rests on the proposition that basic motions or elements are independent of one another and that elements or motions constitute an additive set. This means that once elements or motions are measured, it makes no difference in what sequence they occur.

The evidence to refute this assumption is mountainous.

MTM data was compiled from analysis of 36 drill press operations. After development, the authors conveniently found that the data could be applied to virtually all classes of work. That is, the time value derived for a move of 10 inches is assumed to be universal and can be applied wherever a 10-inch move occurs regardless of what precedes and succeeds the move and regardless of the type of work being performed.

This means that in the eyes of the advocates of standard data, the time value derived for a particular element can be extracted from a job and

1. Harold O. Davidson, *Functions and Bases of Time Standards*, American Institute of Industrial Engineers, Columbus, Ohio, 1957, p. 49.

2. Ibid., p. 50.

applied successfully wherever the element seems to recur. Gerald Nadler has demonstrated that this is an erroneous conclusion.

To prove his point he placed an operator at a table with an angle of tilt ranging from 0 to 90° in 15° increments. The operator was instructed to move his hand from a fixed starting button to a switch a fixed distance away, turn the switch through a 30° angle and return his hand to the starting button. The time for the move therblig was found to vary 16% depending on the angle of tilt.[1]

A University of Wisconsin psychologist, Professor Karl Smith, who has conducted extensive experiments into motor activities, has offered further refutation of the universality assumption. In his laboratories he set up an experiment which provided evidence that times for travel movements are affected by motions involving manipulation.

His experiment centered around a panel on which was mounted a series of switches and buttons. For instance, two toggle switches were mounted at a distance of 24 inches apart, two push buttons were mounted 24 inches apart, two pull buttons were mounted 24 inches apart, two dials were mounted 24 inches apart and so on. Altogether there were eight sets of buttons and switches. Subjects were instructed to press a button, move their hand 24 inches and press the companion button, turn a dial, move their hand 24 inches and turn a companion dial, etc.

Both the subject and the switches and buttons were wired into an extremely accurate timing device which was actuated when the subject's hand broke contact with the first button, switch or dial and stopped when the subject's hand established contact with the second and companion object. In other words, the timing device measured only travel time.

Smith found that the time required for the travel movement varied as much as 58% depending on which of the tasks the subject was performing.

Ralph Barnes and Marvin Mundel found that the standard time for certain basic motions cannot be given as independent values since they may be influenced by other basic motions in the cycle.[2]

The time required to perform a therblig has been shown by one writer to be a function of numerous variables which are not and cannot be accounted for in a standard data system.[3] The variables he mentions are: distance, complexity of action, amount of body used, bimanualness, whether the use of feet accompanies the action, the eye-hand coordination required, the sensory requirements, weight and resistance, the preceding and following therbligs as well as the context and pattern of the task, the direction of movement, the place of the therblig in the motion pattern, the number of therbligs in the pattern and the length of time the pattern will be performed, the possible interaction of two variables, and several other variables as yet unidentified.

RATING AND STANDARD DATA

Proponents of the standard data approach to establishing job standards frequently argue that standard data yields more consistent earnings opportunity than stopwatch data.

1. Gerald Nadler, *"Critical Analysis of Predetermined Motion Time Systems,"* Proceedings of the National Time and Motion Study and Management Clinic (Chicago: Industrial Management Society, 1952).
2. Ralph Barnes and Marvin Mundel, "A Study in Simultaneous Hand Motions," *Studies in Engineering,* Bulletin 17, University of Iowa, 1939.
3. Marvin Mundel, *Motion and Time Study,* 2nd Edition, Prentice-Hall, New York, 1955, pp. 441-443.

In support of their argument they cite the fact that rating, which is a major source of inconsistency in work measurement, is no longer required once the basic data has been developed.

This line of reasoning is particularly attractive to trade unionists and managers who are beset with work load grievances which are a reflection of inconsistent earnings opportunity. In a shop where standards are being developed by stopwatch time studies it is entirely possible that one time study man may have a tendency to set "tight" standards while another may have the opposite tendency.

In addition to overall tendencies, individual time study men may unconsciously vary their concept of normal performance from one job to another, depending on the nature of the work and equipment involved.

The advocate of standard data contends that these difficulties are wholly or largely eliminated because the differences between and within time study men are averaged out and because jobs are not rated at the time standards are actually being applied.

Both the equalizing effect of averaging and the role of rating are subject to serious questioning as "causes" of greater consistency in earnings opportunity under a standard data system.

If a social scientist wishes to ascertain the average age at marriage, the incidence of delinquency among teenagers or the birth rate for a particular socio-economic group he can do so either by counting everyone who falls within the scope of his study or by taking a sample from which he will extrapolate a conclusion. Obviously, it would be difficult if not impossible to count everyone under most circumstances. Therefore he relies on sampling to derive a conclusion. He takes a sample of the ages of newly wedded couples and concludes that the average age at marriage is such and such a figure. The smaller his sample in relation to the total number of marriages, the less likely he is to come up with the "true" average age at marriage. The larger his sample, the more likely he is to approximate the true average. Most important, however, is the fact that even if his sample average and the true average are identical there will still be men and women who marry at an earlier age in life or a later age in life than the average indicates. For them the average age at marriage is little more than an interesting statistic.

In a sense, this is analogous to the process employed in developing standard data. Proponents assert that "errors" made in developing the data will average out because the data is derived by combining the results of numerous observations of work elements and basic motions. This might have a plausible ring to it if the data was developed and applied to only one operation. But the essence of standard data lies in the fact that standard data is developed and applied to a large number of operations. Therefore, while the "errors" in the data may average out for one operation, they will not necessarily average out for all operations.

The individual operator is interested in the adequacy of the standard applied to his job, not in the fact that overall the errors in rates may cancel out.

Davidson likens this line of contention to the rifleman whose overshooting is balanced off by his under-shooting. "An 'over' miss and an 'under' miss do not average out to two bulls-eyes. Neither do a loose rate and a tight rate average out to two correct rates as far as the individual workman, or anyone else, is concerned."[1]

"VALIDATING" STANDARD DATA

One of the interesting and amusing characteristics of the standard data group is their tendency to down grade stopwatch time studies vis-a-vis stopwatch standard data or predetermined motion time systems, on the one hand, and to "prove" their data, on the other hand, by comparing standard data standards with stopwatch standards.

The MTM school is particularly prone to this nonsense. In *Methods-Time Measurement* reference is made to a simultaneous study of 27 jobs by a time study man using a stopwatch and a methods engineer who applied MTM data. As proof of the validity of MTM, the authors report that ". . . The total time allowed by time study for the 27 jobs was 3.4615 minutes. The total time allowed by the methods-time measurement procedure was 3.4414 minutes."[2]

To begin with, the authors are suggesting that the validity of the MTM data is proven because of its close agreement with a work measurement procedure which many standard data advocates criticize. Secondly, they cite an example which precludes analysis of individual differences, i.e., only one person employed each technique; thirdly, they assume that a stopwatch time study and an MTM study can be checked against an unknown (true normal time); and fourth, they imply that on a plant-wide basis the difference between the two systems would be relatively insignificant.

The latter again raises the question of variation among individual rates. The average difference between the two systems may be of minor significance overall. Nevertheless, this is of little consolation and value if there is significant variation among rates which make up the average.

It must also be noted that a high degree of correspondence between two unvalidated systems is no proof of the accuracy of either system.

Predetermined motion time systems, i.e., the microscopic version of standard data, are based on the assumption, as previously reported, that it is possible to isolate, identify and measure irreducible basic motions which will have universal applicability. If this assumption is supportable then it ought to follow that the same motion, regardless of the system, will have the same time value, or, if there are differences among the systems, they will at least be consistent. As the table on page 66 clearly reveals, this is not the case.

Work Factor allows 1.66 more time for a one inch arm movement than MTM while Holmes allows 3.14 more time. For a thirty inch arm movement Work Factor allows .666 of the MTM time and Holmes allows 1.12. Thus we see that there is neither correspondence nor consistency for such a fundamental requirement of work as arm movement.

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1. Harold O. Davidson, *Functions and Bases of Time Standards,* American Institute of Industrial Engineers, Columbus, Ohio, 1959, p. 53.
2. H. B. Maynard, G. J. Stegemerten, and J. L. Schwab, *Methods-Time Measurement,* McGraw-Hill Book Co., New York, 1948, p. 132.

TABLE VII

Comparison of Basic Elements and Times from Three Systems of Standard Data

Basic Element	Distance (inches)	Basic Time — Minutes		
		Work Factor	M-T-M	Holmes
Finger	1	.0016	.00108	.0017
	2	.0017	.00222	.0017
	3	.0019	.00300	.0017
	4	.0023	.00366	.0021
Hand	1	.0016	.00108	.0022
	2	.0017	.00222	.0022
	3	.0019	.00300	.0022
	4	.0023	.00366	.0025
Forearm	45°	.0017	.00576	.0032
	90°	.0023	.00894	.0045
Arm	1	.0018	.00108	.0034
	2	.0020	.00222	.0034
	3	.0022	.00300	.0034
	4	.0026	.00366	.0039
	6	.0032	.00420	.0045
	8	.0038	.00474	.0054
	12	.0046	.00576	.0067
	18	.0055	.00738	.0090
	24	.0063	.00894	.0107
	30	.0070	.01050	.0118
Foot (Hinged Movement)	1	.0020	.00510	.0027
	2	.0022	.00510	.0027
	3	.0024	.00510	.0027
	4	.0029	.00510	.0032
Trunk (Bend)	1	.0026	.00174	.0077
	2	.0029	.00174	.0077
	3	.0032	.00174	.0077
	4	.0038	.00174	.0087
	6	.0047	.00174	.0095
	8	.0054	.00174	.0102
	12	.0066	.00174	.0111
	18	.0080	.00174	.0125
Leg (Hip to toe)	1	.0021	.00426	.0032
	2	.0023	.00426	.0032
	3	.0025	.00426	.0032
	4	.0030	.00426	.0034
	6	.0037	.00426	.0036
	8	.0043	.00570	.0038
	12	.0052	.00858	.0043
	18	.0063	.01290	.0051
Leg (Hip to toe)	1	.0021	.00108	.0048
Side Movement	2	.0023	.00222	.0048
	3	.0025	.00300	.0048
	4	.0030	.00366	.0052
	6	.0037	.00420	.0056
	8	.0043	.00534	.0060
	12	.0052	.01020	.0068
	18	.0063	.01236	.0080
Walk (general case,	1 pace	.0150	.0102	.027
unrestricted)	2 pace	.0260	.0240	.042
	3 pace	.0360	.0360	.056
	5 pace	.0520	.0510	.077
Eye Fixation		.0020	.00438	.0020
Visual Inspection		.0030	.00438	.0025

Source: "A Trade Union Analysis of Time Study," Second Edition, Standard Data, pp. 227-228.

STOPWATCH ELEMENTAL STANDARD DATA

The preceding pages on the subject of standard data have dealt with the major characteristics and criticisms of both the work elements and human motions systems. We will now turn our attention to a somewhat more detailed consideration of both major forms, beginning with the work elements form which derives from stopwatch time studies.

In any given manufacturing establishment it is likely that there will be a number of operations which call for similar processing procedures either wholly or in part. This has led some industrial engineers to the conclusion that predetermined normal performance times can be established for a number of constant and variable manual elements thus obviating the need to time these elements each time a model change occurs or a new operation is scheduled.

On the surface at least, the logic of this assumption is compelling. On a drill press line, for instance, it is quite likely that there will be certain constant and variable elements which are common to virtually all drilling operations. An elementary example of the former would be the element "start machine." The element "drill ½" diameter hole," which would vary with the depth of the hole, the type of drill, the stock, feeds and speeds, tolerances, etc. is an example of a variable element.

Companies which have been making stopwatch time studies for some time are likely to have an accumulation of stopwatch studies of these and other elements which they can use as a basis for developing stopwatch standard data. When the elemental break-off points of existing studies are identical, it is a simple matter to weigh each study, add the results and strike an average. This figure then becomes the standard time for the element or elements in question whenever and wherever they may occur henceforth.

However, many companies will find that existing stopwatch studies are of questionable utility when it comes to developing elemental standard data. This would frequently be the case in those instances where the company did not anticipate converting stopwatch studies into elemental standard data. Stopwatch time studies do not necessitate a fine elemental breakdown. In some cases a breakdown which distinguishes between machine elements and manual elements will be detailed enough.

But in order to justify elemental standard data, the data must possess a degree of universality. To achieve this status it is necessary to reduce the work encompassed by a given element to a minimum. For this and other equally significant reasons, most companies will find that it is necessary to conduct stopwatch studies specifically aimed at development of elemental standard data.

In large part the steps required in developing stopwatch time studies which will serve as a basis for the determination of elemental standard data are identical with the steps required to develop ordinary stopwatch time studies.

The time study man begins by writing up a complete record of the process, material, equipment, stock, jigs, fixtures, etc., required to complete an assembly operation or bring a piece from an unworked to a worked stage. It is imperative that the method, equipment and work station be standardized when studies are being made for the purpose of developing elemental standard data.

While standardization prior to timing is a prerequisite of ordinary stopwatch time studies, it becomes even more important where elemental standard data, is concerned. Changes in fixturing, work station layout or method, which affect performance time, are relatively simple to correct for in the case of an individual stopwatch time study standard. But making appropriate corrections where elemental standard data is in effect is another matter. This is especially true where the data is widely applied rather than being confined to a particular department or type of operation.

Once the time study observer has prepared a record of standardized job circumstances and conditions, he is ready to develop an elemental description of the operation which distinguishes between manual and machine elements and constant and variable elements. In order to achieve the desired universality mentioned above, he will probably reduce the portion of the operation encompassed by each element to a minimum.

Here he encounters some mechanical difficulties because it isn't humanly possible for a time study observer to time a series of short elements in quick succession. Elements of less than .05 minutes duration are difficult to time with acceptable accuracy when they occur in the midst of longer elements. When they occur in quick succession they are impossible to time by normal procedures. Under such circumstances the observer may choose to time elements in groups and solve for the individual elemental times by means of simultaneous equations. When using this procedure, extraordinary care must be exercised to see to it that elemental break-off points are clearly and consistently defined and that watch readings are made in a consistent manner.

Once he has completed his paper work, the time study observer is ready to time the job, rate the operator's performance and develop a "normal" performance time for each element he has studied. So far, as the reader will recognize, the observer has followed the ordinary steps required preparatory to establishing a standard time by means of a stopwatch time study. However, since his objective is to develop normal performance times for elements which are common to a number of different operations rather than for the elements which compose a single operation, there are some distinctions.

Since the observer is intent upon establishing a standard time for an element which is presumed to occur in a number of different operations, it is necessary to time this element under a variety of circumstances. In order to do this it will be necessary to time several different operators, who are required to perform the element or elements in question, under varying circumstances. Whatever procedure the observer chooses, he ought to come up with a set of studies of an element which possess a certain degree of statistical validity. In other words, he will have to time an element for a long enough period, all together, and under a sufficient variety of circumstances and conditions, to come up with a standard time which is representative of all the factors which affect performance time.

This is easier said than done. It is one thing to account for all the factors influencing performance time for one operation. It is another to do so when the observer is developing data which is supposed to be equally applicable wherever it occurs and whenever it occurs.

If the number of observations of an element varies from one study to the next, it becomes necessary to weigh each study accordingly. For instance, twenty observations of an element which resulted in a normal performance time of, say, .045 minutes, should not be given the same weight, when computing standard data, as a study consisting of one hundred observations which gave a normal performance time of .050 minutes. This is why a weighted average is used when preparing elemental standard data.

Here is an example of how this problem would be handled where elemental standard data is being developed for a constant element. Our example assumes that the observer has made ten studies of the element. Column No. 1 represents the "normal" time for the element which emerged from each of the ten studies. Column No. 2 represents the number of observations of the element on each occasion. Column No. 3 represents the product of multiplying Column No. 1 by No. 2.

Column No. 1		Column No. 2		Column No. 3
Normal Time		Number of Observations		Column No. 1 Times Column No. 2
.042 Min.	×	20	=	.84 Min.
.050 "	×	100	=	5.00 "
.045 "	×	50	=	2.25 "
.044 "	×	38	=	1.67 "
.050 "	×	15	=	.75 "
.046 "	×	41	=	1.88 "
.049 "	×	111	=	5.43 "
.042 "	×	82	=	3.44 "
.047 "	×	36	=	1.69 "
.050 "	×	74	=	3.70 "
		567		26.65 "

Normal performance time for the element based on ten studies is found by dividing the total for Column No. 3 by the total for Column No. 2, i.e., Col. No. 3 ÷ Col. No. 2 = normal performance time. Substituting the appropriate figures from our example, we get, 26.65 ÷ 567 = .047 minutes.

The determination of elemental standard data for variable elements calls for a slightly different procedure. It is not possible to use the simple averaging procedure suitable in the case of constant elements because of the presence of independent variables which have a pronounced influence on performance time.

If space is available, the simplest way to account for variable elements is by preparing a table which sets forth the normal performance time for variable elements according to the degree of presence of the variable.

This situation might be illustrated by citing the case of hand polishing operations where the area to be polished varies but the desired finish remains constant. In other words, the time required to polish a square inch of surface remains constant but the number of square inches of surface which must be polished varies.

Using the tabularizing method, the observer simply records the "normal" elemental time he derives from studying polishing elements for various areas such as 144 square inches, 200 square inches, 250 square inches, and so on. As can readily be seen, this method could become quite cumbersome. Because of this, variable elements are often expressed in the form of a curve which shows the relationship between time and the variables which affect time.

When this approach is used, the data derived from studies involving various degrees of presence of the variable factor are plotted on a scatter diagram rather than being recorded on a table. Usually where only one variable is present, time is plotted on the vertical or ordinate axis and the variable is plotted on the horizontal axis, i.e., the abscissa.

To illustrate, let's assume that ten stopwatch time studies of the polishing operation mentioned above produced the results found on page 71.

Visual examination of the data plotted on our hypothetical scatter diagram would suffice, in this instance, for the purpose of fitting a curve to the data. Where the data makes it difficult or unreliable to fit a curve by visual examination, an arithmetic procedure known as the least squares method may be used.

Once a curve has been developed for a variable element, the "normal" time for the element will be derived from examination of the curve rather than actual time studies. Thus, if in the future an operation requiring an operator to polish a 225 square inch area should be scheduled, the standard data analyst would derive "normal" time for the element from examination of the curve even though a study of this specific polishing operation had never been made.

Where more than one variable is present in an element, the development of a scatter diagram and subsequent fitting of a curve become somewhat more complicated. However, the basic objective remains the same.

The work elements form of standard data we have been discussing is of the indigenous variety. That is, it is home grown. It is derived from stopwatch time studies made in the plant where the data is to be applied.

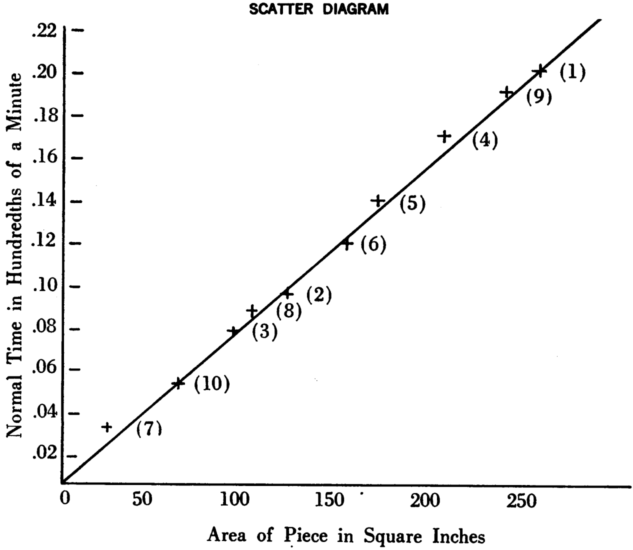
In recent years it has become popular to create elemental standard data by combining data developed for the basic motions which make up predetermined motion time studies.

PREDETERMINED MOTION TIME SYSTEMS

We will now turn our attention to the human motions form of standard data commonly referred to as predetermined motion time systems or synthetic basic motion times. Once again the procedures employed in devel-

Study	Time In Minutes	Area In Square Inches
(1)	.200	250
(2)	.090	125
(3)	.078	100
(4)	.159	200
(5)	.138	175
(6)	.122	155
(7)	.035	48
(8)	.087	117
(9)	.184	232
(10)	.056	71

SCATTER DIAGRAM



(Note: The above data is purely hypothetical and has no significance other than for illustrative purposes.)

oping standards are similar to those which are characteristic of stopwatch time standards. The distinction between the two is confined largely to the determination of "normal" time.

As we have seen, normal time, where stopwatch studies are made, is the result of timing and rating the elements which make up a given operation, an element being defined as "a division of work that can be measured with a timing device . . ."

Determination of "normal" time where a predetermined motion system is in use, on the other hand, involves a basic motion analysis rather than actual timing of the operation. The actual time data has been predetermined. The analyst assigned to develop a standard does not use a stopwatch. His on-the-job observations are confined to preparing a detailed right hand — left hand analysis of the basic motions required to perform a given task.

Once he has completed his basic motion analysis of the operation, he then refers to the tables which set forth the time values developed for each of the basic motions he has described. The total time he comes up with by this procedure represents "normal" time.

It might be appropriate to repeat the fact that all forms of standard data are "predetermined" in the sense that, once the data is developed, the analyst makes either an elemental motion or a basic motion study when he develops a standard, and not a stopwatch time study. The main distinction between stopwatch elemental standard data and "simplified" basic motion times and predetermined motion time systems is the fact that the former consists of either elements which can be timed with a stopwatch or combinations of basic motions, while the latter consists of basic motions which cannot be measured by ordinary stopwatch techniques.

Earlier we called attention to the fact that even though predetermined motion time systems are just now showing signs of coming into vogue, their fundamentals have been in the process of discussion and development for years.

W. G. Holmes, who was one of the early advocates of predetermined motion times, actually carried his data development beyond the usual basic motion (therblig) analysis.[1] In addition to time assignments for finger, hand, foot and arm movements, he provided time data for nerve reactions from the eye to brain or reverse, the knee to the brain or reverse, hear or smell, realize contact, and mental process.

The time values assigned for realize contact, i.e., a nerve reaction, range from .0010 to .0040 minutes. Aside from the highly questionable nature of such a determination, one wonders what the significance of a 4 to 1 variation in reaction time is. Does this mean that a man who sits on a sharp tack will become aware of this fact four times faster than a man who sits on a dull tack?

The time allowed for the nerve reaction "smell" varies from .0025 to .0040 minutes. This conjures up the titillating thought that armed with

1. Walter G. Holmes, *Applied Time and Motion Study,* The Ronald Press Co., New York, 1938, p. 244.

Holmes' data one could establish work standards for such unlikely types of work as criminal detection. At least we could determine the normal time it should take for a detective to "smell a rat."

Of course, the average trade unionist would feel that Holmes' attempt to quantify nerve reaction for work measurement purposes is slightly ludicrous. But Holmes wasn't kidding. He was dead serious. And he occupies a respected niche in the annals of "scientific" management.

If the time data which applies in the case of basic motion time systems is predetermined, how is it predetermined and where does it come from?

WORK-FACTOR

Work-Factor, one of the earlier and more prominent versions, is said to have originated in Philadelphia, Pennsylvania in 1934. Data was accumulated by a staff of from 12 to 25 industrial engineers.

The original motion-time measurements were made by studying some 1,100 experienced factory workers performing "complete factory operations under normal factory conditions."

About 17,000 motions were studied. Some of the time measurements were made with stopwatches having either a 3 second or 6 second sweep hand reading in 1/1000th of a minute.

Extremely short motions were timed with photo-electric timers and 16mm motion picture cameras. All observations were made by a team of two experienced industrial engineers. Simultaneously but independently the observers leveled the performance of each operation by individual motions and by total operation or cycle. At the completion of each study, the sum of the leveled times for individual motions was compared with the leveled time for the cycle. If the two didn't match, all observations and ratings were repeated until the results were in agreement.

From these studies a table containing 430 motion time values was developed. These values are so arranged that performance times for more than 4,000 body-member motions are available.

Work-Factor data is available in three forms or systems: (1) Detailed Work-Factor; (2) Ready Work-Factor; and (3) Abbreviated Work-Factor.

Detailed Work-Factor is used where highly repetitive mass production work and very short cycle work is being performed. Time values are expressed as Work-Factor Time Units equal to 0.0001 minutes.

Ready Work-Factor is applied where medium-quantity production is being measured. This version of Work-Factor is the result of grouping Detailed Work-Factor data into a simplified form for faster learning and application in the shop and office. Time Units are equal to .001 minutes.

Abbreviated Work-Factor was developed to meet the needs of small quantity jobbing shops, maintenance, construction work and other types of heavy work which do not require detailed analysis. Time Units are equal to .005 minutes.

Work-Factor treats the following body member motions as separate and distinct: finger or hand, forearm or arm, forearm swivel, foot, leg, trunk and head.

Where simultaneous motions occur, in most cases, only the controlling motion is analyzed, i.e., the motion requiring the most time.

The effect on performance time of the arrangement and functions of motions in the work pattern is dealt with by means of "Work-Factors." Compensating allowances are made for the effect of repetition as it occurs in mass production versus lack of repetition through quantity tables. The effect of cycle length on performance time is determined from cycle length tables.

Two fundamental factors are present in a Work-Factor Analysis. They are: (1) a description of the basic motions inherent in the performance of a given task; and (2) the identification of the appropriate Work-Factors in the various motions.

A *Basic Motion* is defined as "... any motion the performance of which involves the least amount of difficulty or precision for any given distance and body-member combination; for example, tossing a small, nonfragile object into a tote pan."

A *Work-Factor* is described as "... a unit used as the index of additional time required over and above the Basic Motion Time when motions are performed involving the following variables: (1) Manual Control, (2) Weight or Resistance." The Work-Factor serves as a means of describing the amount of control or weight involved in the performance of basic motions.

More specifically, Work-Factor acknowledges the following factors as having an influence on performance time over and above the time required to perform a Basic Motion:

W = Weight or Resistance

S = Directional Control (Steer)

P = Care (Precaution)

U = Change Direction

D = Definite Stop

As can be seen, a basic motion may be influenced by all or none of the above factors. It should also be noted that the same adjustment is made in basic time when manual control or weight or resistance are present, regardless of the type of Work-Factor. In other words, there is an assumption that all types of work factors have an identical differential effect on performance time. This is a questionable assumption.

The main distinction between a standard established by stopwatch time studies and a standard established by some form of standard data is seen in the procedure used to develop "normal" time.

When a standard is developed from stopwatch time studies, the time study man derives "normal" time for the job in question by *timing* and *rating* an operator engaged in the performance of the job. In cases where some form of standard data is being used, the time study man describes the elements or basic motions employed by the operator in performing the task and then compares this description with motion-time data peculiar to the standard data system he is using.

Consequently, the time study man using standard data actually dispenses with two prominent features of stopwatch time studies: (1) timing an operator engaged in the performance of the job for which a standard is desired and; (2) rating the performance of the operator.

Thus, the analyst using a standard data system such as Work-Factor lays aside his stopwatch, time study sheet and clipboard and, in their place, arms himself with a tape measure and a Work-Factor Motion-Time Table. A facsimile of this Table is printed in the Appendix.

The Work-Factor Motion-Time Table consists of data for Arm (A) movements, Leg (L) movements, Trunk (T) movements, Finger-hand (F, H) movements, Foot (FT) movements, Forearm Swivel (FS), Walking Time, Visual Inspection and Head Turn.

The reader should take note of the fact that one Work-Factor Time Unit is the equivalent of 6/1000 of a second, 1/10,000 of a minute or 167/100,-000,000 of an hour.

Use of the Work-Factor Motion-Time Table can be illustrated by reference to the following examples. These examples are all found in the *Industrial Engineering Handbook.*[1]

Example 1.

The arm is moved 10 inches to toss a small object aside. This is a *Basic Motion.*

1. Refer to the Arm (A) Table.
2. Find 10 in the Distance Moved column.
3. Opposite 10, in the column headed Basic, find the value 42.
4. Since a Work-Factor Time Unit is equal to .0001 (1/10,000) minutes the time for this motion is 0.0042 minutes.

Example 2.

The arm reaches 20 inches to pick up a bolt from a bin. This is a *Definite Stop Motion.*

1. Refer to the Arm Table.
2. Sight down the Distance Moved column to 20.
3. Since a Definite Stop Work-Factor is involved, the motion is a one Work-Factor Motion and the time value sought appears opposite the 20, under the column headed 1 Work-Factor.
4. Therefore, the time for this motion is 80 Work-Factor Time Units or, 0.0080 minutes.

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1. H. B. Maynard, Editor-in-Chief, McGraw-Hill Book Co., Inc. 1956.

Example 3.

A man moves a building brick weighing 4 pounds, 30 inches from a pile, placing it on a work table. This is a *Definite Stop and Weight Motion.*

1. First, refer to the bottom of the Arm Table to determine how many degrees of motion difficulty Work-Factors are involved because of the weight of the brick. Since the worker is a male and the weight involved is between the limits 2 and 7 pounds, one Work-Factor is allowed for Weight.
2. The motion also requires one Work-Factor for the Definite Stop involved in placing the brick on the table. *Two* Work-Factors are, therefore, necessary.
3. In the Distance Moved column find 30.
4. Opposite 30 in the column headed 2 Work-Factors find the value 119.
5. The time for this motion is 0.0119 minutes.

Since the first example consists of a Basic Motion in isolation, no additions to compensate for complicating difficulties are allowed. However, in the second example the arm is moved 20 inches to a bin which means that there will be an interruption in the motion when the hand comes in contact with the bolt in the bin. Because of this, one Work-Factor is added to the Basic Time allowed to move the arm 20 inches.

In the third instance we are introduced to an example of Work-Factor Analysis where two degrees of motion difficulty are present. A brick weighing 4 pounds is moved 30 inches, from a pile to a table. One Work-Factor is allowed for the weight of the brick and one Work-Factor is allowed for placing the brick on the table.

Notice that the differential by which the basic time is modified is the same for Definite Stop as for Weight. This deals with a fundamental assumption of Work-Factor. As previously mentioned, regardless of the kind of complicating difficulty, it is assumed that the differential effect on basic motions is identical.

This "...basic concept of the system appears susceptible to question in view of the fact that each of these 'factors' has been assigned the same differential effect on time for different lengths of movement. To illustrate, let us consider the arm movement. The addition of *any one* work factor increases the basic time by increments varying from .0008 minutes for a one inch movement, up to .0026 minutes for a forty inch movement. These same differential increments are applied whether the factor happens to be 'definite stop' occurring only at the end of the movement or a 'weight' factor (which likely would have an appreciable effect on the entire movement). The assumption of identical differential effects for all types of work factors is scarcely tenable . . ."[1]

In addition to this rather fundamental criticism of the Work-Factor approach to standard data, it should also be noted that Work-Factor data does not differentiate between motions to the front and rear, between low

1. Harold O. Davidson, *Functions and Bases of Time Standards,* American Institute of Industrial Engineers, Columbus, Ohio, 1959, p. 51.

motions and high motions, and no provision is made for the effect of simultaneous motions on performance time.

MTM

Methods-Time Measurement and Work-Factor have much in common. Both represent human motions versions of standard data. Both assume that it is possible to identify and measure unique, irreducible motions, which will have universal validity as a form of work measurement. Both assume that work elements or basic motions are independent of each other and therefore constitute an additive set, i.e., the total time required to perform a given task is the sum of the individual elements or basic motions which make up the task.

As with Work-Factor, stopwatch measurement of a job is abandoned in favor of motion analysis followed by application of predetermined time values. Methods-Time Measurement (MTM) is defined as "a procedure which analyzes any manual operation or method into the basic motions required to perform it, and assigns each motion a pre-determined time standard which is determined by the nature of the motion and the conditions under which it is made."[1]

MTM data, reproduced in the Appendix, consists of data for Reach (R), Move (M), Turn and Apply Pressure (T and AP), Grasp (G), Position (P), Release (RL), Disengage (D), Eye Travel Time and Eye Focus (ET and EF), Body, Leg and Foot Motions and Simultaneous Motions.

Where Work-Factor accounts for weight or resistance influencing the time required to perform a basic motion by means of the addition of time units called Work-Factors, MTM achieves the same effect by means of sub-classes or cases. Thus, the basic motion *Reach* is sub-divided into five different cases depending on what the operator will be required to do at the end of the reach.

A *Reach* to an object in a fixed location or to an object held in the other hand is considered a class A reach. A *Reach* to a single object in a location which varies from cycle to cycle is considered a class B reach, and so on.

Similar sub-divisions are provided for other MTM basic motions such as *Move, Grasp* and *Position.*

In the preceding pages we cited the example of a Work-Factor analysis which involved reaching 20 inches to pick up a bolt from a bin. The Work-Factor Standard for this task, which would be described as A20D, was 80 Work-Factors, or 0.0080 minutes.

The MTM analysis of this same task would call for a coded description of R20C or 19.8 T.M.U.'s (Time Measurement Units). Since one T.M.U. is equal to .00001 hours, the MTM standard is equal to .000198 hours or 0.01188 minutes.

Niebel cites a comparison between Work-Factor and MTM, made by *Modern Industry* magazine, which reveals a 12.1 percent difference between the standards the two systems would allow for the same task.[2] This discrep-

1. H. B. Maynard, G. J. Stegemerten, and J. L. Schwab, *Methods-Time Measurement,* McGraw-Hill Book Co., New York, 1948.
2. Benjamin W. Niebel, *Motion and Time Study,* Revised Edition, Richard D. Irwin, Inc., Homewood, Illinois, 1958, p. 203.

ancy is attributed to the fact that Work-Factor standards are based on the "experienced, skilled" worker while MTM standards are based on the "normal" or "average" worker. It is possible that this is the cause of the difference although the distinction between the "experienced, skilled" worker and the "normal" or "average" worker is a nebulous one at best. It is also possible, indeed likely, that the difference is attributable to differing conclusions with respect to the time required to perform basic motions.

Quite frequently union negotiators run into the claim that the validity of MTM data is attested to by the extent to which MTM standards harmonize with stopwatch time study standards.

For example, on page 65 reference was made to an MTM study of 27 jobs which were measured by observers employing the stopwatch time study technique and MTM. "Both men studied each job at the same time, so the factor of method was held constant. The time study man made a stopwatch time study. The methods engineer observed the operation and applied the methods-time data. He also rated the performance of the operator for skill and effort, since he was more skilled at this than the time study man who was a comparatively new man."[1]

Going on, the authors reported that "... The total time allowed by time study for the 27 jobs was 3.4615 minutes. The total time allowed by the methods-time measurement procedure was 3.4414 minutes."

There is no doubt that this represents a remarkable degree of agreement between the total time allowed for 27 jobs by stopwatch studies and methods-time data. However, this doesn't represent "proof" of the validity of MTM any more than identical times on two wrist watches represents proof that the watches show the correct time. Both watches could be wrong! A comparison between MTM and stopwatch studies for the purpose of verifying MTM data is essentially a comparison between two unvalidated techniques.

Furthermore, the procedure followed in checking methods-time data against stopwatch studies, is questionable. The fact that only one analyst was applying each technique in itself raises serious questions. This precludes any analysis of the effect of individual differences among observers.

The close coincidence between the two total times doesn't tell the whole story either. Davidson calls attention to the fact that the "differences between individual rates varied from minus 9% to plus 11%."[2] As he suggests, one loose rate and one tight rate doesn't add up to two correct rates as far as the individual worker is concerned.

Davidson also raises another fundamental question regarding the potential validity or accuracy of MTM, or any standard data system for that matter. He first takes note of the acknowledgement by Maynard, Stegemerten and Schwab that "... No two operators perform in exactly the same way, for although they may perform each major or timestudy element in the same order, within each major element the *basic* elements will vary" and then goes on to ask, in view of this concession, how the methods ana-

1. H. B. Maynard, G. J. Stegemerten, and J. L. Schwab, *Methods-Time Measurement*, McGraw-Hill Book Co., New York, 1948, p. 132.
2. Harold O. Davidson, *Functions and Bases of Time Standards*, American Institute of Industrial Engineers, Columbus, Ohio, 1959, p. 53.

lyst will identify the correct method. When a methods analyst goes out to establish a standard, how does he determine which operator to derive the method from if no two operators "perform in exactly the same way?"

This problem is likened by Davidson to the critical decision inherent in determining the rating factor, "the elimination of which has been one of the principal advantages claimed for the standard data approach."

Davidson concludes his evaluation of the standard data approach to work measurement with the observation that "... As the potential precision of the technique is increased by refining the categories of basic elements (i.e., reducing the non-uniqueness of elements) the observed number of methods differences within and among operators will also be increased, and the problem of selecting from among them the 'proper' set of basic elements magnified. Similarly, the opportunities for two or more analysts to produce differing descriptions (and differing standards) of the same observed performance are increased."

XIV . . . WORK SAMPLING

One final form of work measurement remains to be discussed. In recent years a technique which has seen limited use as a means of determining unavoidable delay allowances has begun to emerge as a process by which standards as such may be established. The technique in question is called "work sampling."

Before describing this procedure in detail, it should be recalled that work measurement in its myriad forms is based on the sampling concept. Stopwatch time studies, elemental standard data, predetermined motion time systems — all are founded on the assumption that it is possible to predict how much time will be required to perform a given element or basic motion simply by measuring that motion at a given point in time.

A standard based on a thirty-minute, a forty-minute or an all-day stopwatch time study is presumed to represent the correct time for performing a task in the future so long as there are no changes in method, material, conditions, equipment, etc. Thus a standard based on a thirty-minute study may be in effect for months and even years. The same line of reasoning applies to stopwatch standard data and predetermined motion-time systems.

If the observer's standard is based on a study made under unrepresentative conditions, the standard will not hold up. This might be true in the case of a study of machining of forgings where a fresh die is in use. Later, after the standard has been established, and the die has washed out, the operator will be required to remove more material than he was during the time when the study was made.

A more refined version of this underlying assumption of work measurement has been applied to the determination of unavoidable delays, to a relatively limited extent, for a number of years. Instead of relying on "informed" guesses or production studies to determine how much should be allowed for interruptions or delays beyond the control of the operator, some industrial engineers have turned to ratio-delay studies or work sampling (the term "work sampling" has now largely replaced the term "ratio-delay" in work measurement terminology).

The procedure is based on sampling theory. However, rather than going through the procedures typical of stopwatch studies, the industrial engineer makes a number of instantaneous, random observations of the job in question. By this process the observer determines the relationship between working and non-working time.

A stopwatch is not used and no measurement in the traditional sense is involved. The observer simply records whether the operator engaged in the operation under study was working or not working as he (the observer) passed the work station at random intervals.

If the operator is engaged in the performance of either a cyclical or non-cyclical element, the observer makes a mark in a column set up for that purpose. Likewise, if the operator is not working by reason of waiting for stock, conversation with a supervisor, attention to personal needs, etc., the observer makes a mark in a column set up for that purpose. Naturally, the delays must be identified and specified according to type. A delay caused by attention to personal needs should not become a part of the data used in computing the unavoidable delay allowance.

If, out of 3,000 random observations, the observer has recorded 2,850 instances when the operator was engaged in the performance of cyclical and non-cyclical elements and 150 instances when the operator was not working by reason of an unavoidable delay, we know that the unavoidable delay allowance equals 5.26%, i.e., 150 ÷ 2850 = 5.26%.

At this point it might be well to define what is meant by the term "random" as it is applied to work sampling. A "random" sample is a sample selected without reference to any predictable pattern. For instance, if the observer compiled 3,000 observations for an operation by making observations every half hour, his sample would not be based on random observations.

How does the observer regulate his observations of the work under study so as to achieve random sampling? He has at least two possibilities. He can set up a random schedule by reference to a table of random numbers,[1] or he can simply list all the minutes of the working day on individual slips of paper, throw them in a hat, and draw out as many slips as he needs to make the desired number of observations each day.

Thus, if the industrial engineer plans to make 30 observations each day for 90 days, he would withdraw 30 slips of paper from the hat and plan to pass by the work station under study at the times indicated on the slips of paper.

This procedure, i.e., work sampling, as previously mentioned, is now finding limited application in the actual development of work standards as well as in the determination of delay allowances. One reason for this is the economies involved. Using this method, one observer can be engaged in accumulating data for standards on dozens of operations at one time.

The reasoning behind this development is simple. If it is possible to develop reliable delay allowance data from work sampling, why isn't it possible to carry the procedure one step farther and develop data for cyclical and non-cyclical elements.

There is, in theory, no reason why work sampling cannot be used to establish job standards. However, in practice, as is so often the case, certain problems arise.

To begin with, work sampling is based on the theory of probability. And yet, there is no conclusive reason to believe that this theory applies to industrial processes. The theory of probability is based on the assumption that when a sufficient amount of data has been accumulated, that data will assume the shape of the normal distribution curve. That is, there will be an equal tendency for the data in question to fall either above or below

1. Benjamin W. Niebel, *Motion and Time Study*, Revised Edition, Richard D. Irwin, Inc., Homewood, Illinois, 1958, pp. 480-481.

the arithmetic mean. However, in actual practice, data collected from the observation of industrial processes frequently does not fit this pattern. There is, in the language of the statistician, a tendency for the data to be skewed.

The old time study man's Nemesis, i.e., rating, also rears its ugly head. While many time study men have ignored rating in the application of work sampling on the assumption that work pace does not influence the results, there is growing recognition of the fact that work pace cannot be ignored. Nadler, commenting to this effect has observed that "...when accuracy is required the operator's pace definitely affects work sampling results"[1] and, in another article, "...a person who performs more rapidly than another does not take the same proportion of time of the total day for many of the activities."[2]

Knowing how substantially an observer's judgment of pace can influence the outcome of a standard when the observer has ample opportunity to evaluate operator performance, one wonders what to expect from rating based on a fleeting observation of the operator. In other words, as far as performance rating is concerned, work sampling suffers from the same disability which afflicts stopwatch time studies and standard data.

CONCLUSION

In concluding this pamphlet on work measurement, notice should be taken of the fact that wage incentives are a frequent, although unessential, companion of work standards. However, wage incentives are a subject unto themselves, having no direct bearing on the method by which standards are established.

The premise stated at the outset of the pamphlet should also be reasserted, namely, that work measurement and work standards, by their very nature, are a proper subject of collective bargaining.

Work measurement in its various forms does not provide a final, definitive answer to the age old question, "What is a fair day's work?" The industrial engineer is not a scientist. The "tools" of his trade are, by modern standards, crude at best. His judgment, in the final analysis, has a more fundamental effect on the final determination of a standard, than anything else. Where judgment is involved there will be differences of opinion. And where differences of opinion are involved, collective bargaining offers the most promising means of resolving those differences.

Finally, in addition to being a proper subject for collective bargaining because of the extent to which judgment is inherent in their determination, work standards are also a proper subject for negotiations under the law as repeatedly affirmed by NLRB and court rulings and decisions.

Management is required by law to negotiate with respect to every aspect of job standards and to furnish the union with data developed in the process of arriving at such standards.

1. G. Nadler, "Pace as a Factor in Work Sampling," *Factory Management and Maintenance*, July 1961, pp. 172-173.
2. G. Nadler, "New Applications for Work Sampling," *Proceedings 15th Annual S.A.M.-A.S.W.E. Management Engineering Conference*, April 1960, New York City.

APPENDIX

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> Quick, Duncan and Malcolm, WORK-FACTOR TIME STANDARDS, McGraw-Hill Book Company, Inc.
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> Maynard (Editor), INDUSTRIAL ENGINEERING HANDBOOK, McGraw-Hill Book Company, Inc.
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For additional information on the Work-Factor System, refer to 'Work-Factor Time Standards,' McGraw-Hill Book Company, Inc."

WOFAC*

Work-Factor® MOTION TIME TABLE
for
DETAILED ANALYSIS
TIME IN Work-Factor® UNITS

WOFAC*

* A Work-Factor Service Mark

DISTANCE MOVED	BASIC	WORK-FACTORS 1	2	3	4
(A) ARM—Measured at Knuckles					
1"	18	26	34	40	46
2"	20	29	37	44	50
3"	22	32	41	50	57
4"	26	38	48	58	66
5"	29	43	55	65	75
6"	32	47	60	72	83
7"	35	51	65	78	90
8"	38	54	70	84	96
9"	40	58	74	89	102
10"	42	61	78	93	107
11"	44	63	81	98	112
12"	46	65	85	102	117
13"	47	67	88	105	121
14"	49	69	90	109	125
15"	51	71	92	113	129
16"	52	73	94	115	133
17"	54	75	96	118	137
18"	55	76	98	120	140
19"	56	78	100	122	142
20"	58	80	102	124	144
22"	61	83	106	128	148
24"	63	86	109	131	152
26"	66	90	113	135	156
28"	68	93	116	139	159
30"	70	96	119	142	163
35"	76	103	128	151	171
40"	81	109	135	159	179
Weight in Lbs. Male	2	7	13	20	UP
Weight in Lbs. Fem.	1	3½	6½	10	UP
(T) TRUNK—Measured at Shoulder					
1"	26	38	49	58	67
2"	29	42	53	64	73
3"	32	47	60	72	82
4"	38	55	70	84	96
5"	43	62	79	95	109
6"	47	68	87	105	120
7"	51	74	95	114	130
8"	54	79	101	121	139
9"	58	84	107	128	147
10"	61	88	113	135	155
11"	63	91	118	141	162
12"	66	94	123	147	169
13"	68	97	127	153	175
14"	71	100	130	158	182
15"	73	103	133	163	188
16"	75	105	136	167	193
17"	78	108	139	170	199
18"	80	111	142	173	203
19"	82	113	145	176	206
20"	84	116	148	179	209
Weight in Lbs. Male	11	58	UP	—	—
Weight in Lbs. Fem.	5½	29	UP	—	—

DISTANCE MOVED	BASIC	WORK-FACTORS 1	2	3	4
(L) LEG—Measured at Ankle					
1"	21	30	39	46	53
2"	23	33	42	51	58
3"	26	37	48	57	65
4"	30	43	55	66	76
5"	34	49	63	75	86
6"	37	54	69	83	95
7"	40	59	75	90	103
8"	43	63	80	96	110
9"	46	66	85	102	117
10"	48	70	89	107	123
11"	50	72	94	112	129
12"	52	75	97	117	134
13"	54	77	101	121	139
14"	56	80	103	125	144
15"	58	82	106	130	149
16"	60	84	108	133	153
17"	62	86	111	135	158
18"	63	88	113	137	161
19"	65	90	115	140	164
20"	67	92	117	142	166
22"	70	96	121	147	171
24"	73	99	126	151	175
26"	75	103	130	155	179
28"	78	107	134	159	183
30"	81	110	137	163	187
35"	87	118	147	173	197
40"	93	126	155	182	206
Weight in Lbs. Male	8	42	UP	—	—
Weight in Lbs. Fem.	4	21	UP	—	—
(F, H) FINGER-HAND—Measured at Finger Tip					
1"	16	23	29	35	40
2"	17	25	32	38	44
3"	19	28	36	43	49
4"	23	33	42	50	58
Weight in Lbs. Male	⅔	2½	4	UP	—
Weight in Lbs. Fem.	⅓	1¼	2	UP	—
(Ft) FOOT—Measured at Toe					
1"	20	29	37	44	51
2"	22	32	40	48	55
3"	24	35	45	55	63
4"	29	41	53	64	73
Weight in Lbs. Male	5	22	UP	—	—
Weight in Lbs. Fem.	2½	11	UP	—	—
(FS) FOREARM SWIVEL—Measured at Knuckles					
45°	17	22	28	32	37
90°	23	30	37	43	49
135°	28	36	44	52	58
180°	31	40	49	57	65
Torque Lbs. Ins. Male	3	13	UP	—	—
Torque Lbs. Ins. Fem.	1½	6½	UP	—	—

Work-Factor® SYMBOLS

W — Weight or Resistance
S — Directional Control (Steer)
P — Care (Precaution)
U — Change Direction
D — Definite Stop

WALK TIME

TYPE	30" PACES 1	2	OVER 2
General	Analyze from Table	260	120 + 80/Pace
Restricted		300	120 + 100/Pace

Add 100 for 120° — 180° Turn at Start or Finish

Up Steps (8" Rise — 10" Flat)	126
Down Steps	100

MENTAL PROCESS
(From Simplified Work-Factor)

Focus	20 units
Inspect	30 units/Pt.
React	20 units

Head Turn 45° 40, 90° 60

1 Time Unit = .006 Second
= .0001 Minute
= .00000167 Hour

WORK-FACTOR® TABLES (Continued)

COMPLEX GRASPS FROM RANDOM PILES

SIZE (Major dimension or length)		SOLIDS & BRACKETS [Thickness over 3/64" (.0469")] Blind — Simo	SOLIDS & BRACKETS Visual — Simo	THIN FLAT OBJECTS — THICKNESS (less than 1/64) 0-.0156" Blind — Simo	(less than 1/64) Visual — Simo	(1/64 to 3/64) .0156"-.0469" Blind — Simo	(1/64 to 3/64) Visual — Simo	CYLINDERS AND REGULAR CROSS SECTIONED SOLIDS — DIAMETER 0-.0625" (1/16) Blind — Simo	.0626"-.125" (1/8) Blind — Simo	.1251"-.1875" (3/16) Blind — Simo	.1876"-.5000" (1/2) Blind — Simo	.1876"-.5000" (1/2) Visual — Simo	.5001" & up (over 1/2) Blind — Simo	.5001" & up (over 1/2) Visual — Simo	Add for Entangled, Nested or Slippery Objects * — Simo
.0000"- .0625"	1/16" & less	120 172		— —		131 189									17 26
.0626"- .1250"	over 1/16" to 1/8"	79 111		108 154		85 120		85 120							12 18
.1251"- .1875"	over 1/8" to 3/16"	64 88	Blind	102 145	Blind	74 103	Blind	79 111	74 103		Solids				12 18
.1876"- .2500"	over 3/16" to 1/4"	48 64		72 100		56 76		79 111	68 94	64 88					8 12
.2501"- .5000"	over 1/4" to 1/2"	40 52		64 88		48 64		62 85	56 76	56 76	44 58	44 58			8 12
.5001"-1.0000"	over 1/2" to 1"	40 52	32 40	64 88	60 82	48 64	44 58	62 85	56 76	48 64	48 64	44 58	40 52	32 40	8 12
1.0001"-4.0000"	over 1" to 4"	37 48	20 22	53 72	36 46	45 60	28 34	56 76	48 64	40 52	40 52	36 46	37 48	20 22	8 12
4.0001" & up	over 4"	46 61	20 22	70 97	44 58	62 85	36 46	56 76	48 64	40 52	40 52	36 46	37 48	20 22	9 14

* Add the indicated allowances when objects: (a) are entangled (not requiring two hands to separate); (b) are nested together because of shape or film; (c) are slippery (as from oil or polished surface). When objects both entangle and are slippery, or both nest and are slippery, use double the value in the table.

ASSEMBLE

TARGET DIAMETER	CLOSED TARGETS — Ratio of Plug ÷ Target: To .224	.225 to .289	.290 to .414	.415 to .899	.900 to .934	.935 to 1.000	OPEN TARGETS — Ratio of Plug ÷ Target: To .224	.225 to .289	.290 to .414	.415 to .899	.900 to .934	.935 to 1.000
.875" & up	(D*) 18	(D*) 18	(D*) 18	(1/4) 25	(1/4**) 51	(1/4***) 59	(D*). 18	(D*) 18	(D*) 18	(D*) 18	(1/4**) 51	(1/4***) 59
.625" to .874"	(D*) 18	(D*) 18	(SD*) 18	(1/4) 25	(1/4**) 51	(1/4***) 59	(D*) 18	(D*) 18	(D*) 18	(SD*) 18	(1/4**) 51	(1/4***) 59
.375" to .624"	(SD*) 18	(SD*) 18	(1/4) 25	(1/2) 31	(1/2**) 57	(1/2***) 65	(SD*) 18	(SD*) 18	(SD*) 18	(1/2) 31	(1/2**) 57	(1/2***) 65
.225" to .374"	(1/2) 31	(1) 44	(1) 44	(1 1/2) 57	(1 1/2**) 83	(1 1/2***) 91	(1/4) 25	(1/2) 31	(1/2) 31	(3/4) 38	(3/4**) 64	(3/4***) 72
.175" to .224"	(1) 44	(1) 44	(1) 44	(1 1/2) 57	(1 1/2**) 83	(1 1/2***) 91	(1/2) 31	(1/2) 31	(1/2) 31	(3/4) 38	(3/4**) 64	(3/4***) 72
.125" to .174"	(1) 44	(1 1/4) 51	(1 1/2) 57	(1 1/2) 57	(1 1/2**) 83	(1 1/2***) 91	(3/4) 38	(1) 44	(1) 44	(1) 44	(1**) 70	(1***) 78
.075" to .124"	(2 1/2) 83	(2 1/2) 83	(2 1/2) 83	(2 1/2) 83	(2 1/2**) 109	(2 1/2***) 117	(1 1/4) 51	(1 1/4) 51	(1 1/4) 51	(1 1/4) 51	(1 1/4**) 77	(1 1/4***) 85
.025" to .074"	(3) 96	(3) 96	(3) 96	(3) 96	(3**) 122	(3***) 130	(1 1/2) 57	(1 1/2) 57	(1 1/2) 57	(1 1/2) 57	(1 1/2**) 83	(1 1/2***) 91

* Letters indicate Work Factors in move preceding Assemble. ** Requires A(X)S Upright for all ratios of .900 and greater. (Table value includes A1S Upright.) *** Requires A(Y)S Upright and A(Z)P Insert for all ratios of .935 and greater. (Table value includes A1S Upright and A1P Insert.)

DISTANCE BETWEEN TARGETS

Distance Between Targets	% Addition to Align	Method of Align
0— .99"	Neg.	Simo
1— 1.99"	10%	Simo
2— 2.99"	30%	Simo
3— 4.99"	50%	Simo
5— 6.99"	70%	Simo
7—14.99"	Align and Insert first end, then Align* and Insert second end.	
15" & up	Align and Insert first end, Head Turn and Inspect second end, then Align* and Insert second end.	

* If connected, treat 2nd Assemble as Open Target with no Upright

GRIPPING DISTANCE

Distance from Gripping Point to Align Point	% Addition to Align	Length of Upright Motion
0— 1.99"	Neg.	1"
2— 2.99"	10%	1"
3— 4.99"	20%	2"
5— 6.99"	30%	2"
7— 9.99"	40%	3"
10—14.99"	60%	5"
15—19.99"	80%	6"
20" & up	100%	7" & up

BLIND TARGETS

Blind Distance	% Addition to Align — Permanent	Temporary
.0— .49"	20%	0%
.5— .99"	30%	10%
1.0— 1.99"	40%	20%
2.0— 2.99"	70%	30%
3.0— 4.99"	130%	50%
5.0— 6.99"	250%	70%
7.0—10.00"	380%	120%

GENERAL RULES FOR ASSEMBLE

1. When required add W and P Work-Factors to all Assemble Motions according to rules for Transports.
2. Reduce number of Aligns by 50% when hand is rigidly supported.
3. Where Gripping Distance, Distance Between and Blind Targets are involved, add each percentage to Original Aligns. Don't pyramid percentages.
4. Aligns for Surface Assemble are taken from .224 column and are A1SD Motions.
5. Index is F1S, A1S or FS45°S.

PRE-POSITION

Number of Points Satisfactory for Use	Per cent PP Required	Type of Pre-position: Optimum (3/8 in. or Over) 3F1	Very Small (Under 3/8 in.) 5F1	Medium One Hand (Over 2 X 2 X 1/2 in.) 4F1	Medium Two Hands (Over 3 X 3 X 1/2 in.) 2F1 + A4D	Large Two Hands (Over 8 X 8 in.) 2F1W + A8D
Two or more sides up: Four, three, or two Opposite Points	0	—	—	—	—	—
Two Adjacent Points	25	12	20	16	18	25
One Point Only	50	24	40	32	35	50
One specific side up: Four, three, or two Opposite Points	50	24	40	32	35	50
Two Adjacent Points	62 1/2	30	50	40	44	63
One Point Only	75	36	60	48	53	75
From stack, etc.:	100	48	80	64	70	100

1. PP of more than one Finger Motion or one wrist turn cannot be done Simo with a Move.
2. End for End PP in fingers, 3F1—50%, 24 Units.
3. Other PP must be analyzed. Table is a guide.

POST-DISENGAGE TRAVEL TABLE

Resistance to Disengage, lb.	Post-disengage Travel, in.
0.0— 2.0	Neg.
2.1— 7.0	3
7.1—13.0	6
13.1—20.0	10

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WOFAC*

ADMINISTRATIVE OFFICE
21 Euclid Avenue East, Haddonfield, New Jersey
HAzel 9-5900

METHODS-TIME MEASUREMENT APPLICATION DATA IN TMU

1 TMU = .00001 hour
= .0006 minute
= .036 second

Do not attempt to use this chart or apply Methods-Time Measurement in any way unless you understand the proper application of the data. This statement is included as a word of caution to prevent difficulties resulting from misapplication of the data.

MTM ASSOCIATION for STANDARDS AND RESEARCH
Huron Towers, 2200 Fuller Road
ANN ARBOR, MICHIGAN

MTMA 101
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APRIL 1965

TABLE I—REACH—R

Distance Moved Inches	Time TMU A	Time TMU B	Time TMU C or D	Time TMU E	Hand in Motion A	Hand in Motion B
¾ or less	2.0	2.0	2.0	2.0	1.6	1.6
1	2.5	2.5	3.6	2.4	2.3	2.3
2	4.0	4.0	5.9	3.8	3.5	2.7
3	5.3	5.3	7.3	5.3	4.5	3.6
4	6.1	6.4	8.4	6.8	4.9	4.3
5	6.5	7.8	9.4	7.4	5.3	5.0
6	7.0	8.6	10.1	8.0	5.7	5.7
7	7.4	9.3	10.8	8.7	6.1	6.5
8	7.9	10.1	11.5	9.3	6.5	7.2
9	8.3	10.8	12.2	9.9	6.9	7.9
10	8.7	11.5	12.9	10.5	7.3	8.6
12	9.6	12.9	14.2	11.8	8.1	10.1
14	10.5	14.4	15.6	13.0	8.9	11.5
16	11.4	15.8	17.0	14.2	9.7	12.9
18	12.3	17.2	18.4	15.5	10.5	14.4
20	13.1	18.6	19.8	16.7	11.3	15.8
22	14.0	20.1	21.2	18.0	12.1	17.3
24	14.9	21.5	22.5	19.2	12.9	18.8
26	15.8	22.9	23.9	20.4	13.7	20.2
28	16.7	24.4	25.3	21.7	14.5	21.7
30	17.5	25.8	26.7	22.9	15.3	23.2

CASE AND DESCRIPTION
A Reach to object in fixed location, or to object in other hand or on which other hand rests.
B Reach to single object in location which may vary slightly from cycle to cycle.
C Reach to object jumbled with other objects in a group so that search and select occur.
D Reach to a very small object or where accurate grasp is required.
E Reach to indefinite location to get hand in position for body balance or next motion or out of way.

TABLE II—MOVE—M

Distance Moved Inches	Time TMU A	Time TMU B	Time TMU C	Hand in Motion B
¾ or less	2.0	2.0	2.0	1.7
1	2.5	2.9	3.4	2.3
2	3.6	4.6	5.2	2.9
3	4.9	5.7	6.7	3.6
4	6.1	6.9	8.0	4.3
5	7.3	8.0	9.2	5.0
6	8.1	8.9	10.3	5.7
7	8.9	9.7	11.1	6.5
8	9.7	10.6	11.8	7.2
9	10.5	11.5	12.7	7.9
10	11.3	12.2	13.5	8.6
12	12.9	13.4	15.2	10.0
14	14.4	14.6	16.9	11.4
16	16.0	15.8	18.7	12.8
18	17.6	17.0	20.4	14.2
20	19.2	18.2	22.1	15.6
22	20.8	19.4	23.8	17.0
24	22.4	20.6	25.5	18.4
26	24.0	21.8	27.3	19.8
28	25.5	23.1	29.0	21.2
30	27.1	24.3	30.7	22.7

Wt. Allowance: Wt. (lb.) Up to	Factor	Constant TMU
2.5	1.00	0
7.5	1.06	2.2
12.5	1.11	3.9
17.5	1.17	5.6
22.5	1.22	7.4
27.5	1.28	9.1
32.5	1.33	10.8
37.5	1.39	12.5
42.5	1.44	14.3
47.5	1.50	16.0

CASE AND DESCRIPTION
A Move object to other hand or against stop.
B Move object to approximate or indefinite location.
C Move object to exact location.

TABLE III—TURN AND APPLY PRESSURE—T AND AP

Weight	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
	Time TMU for Degrees Turned										
Small— 0 to 2 Pounds	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium—2.1 to 10 Pounds	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large— 10.1 to 35 Pounds	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

APPLY PRESSURE CASE 1—16.2 TMU. APPLY PRESSURE CASE 2—10.6 TMU

TABLE IV—GRASP—G

Case	Time TMU	DESCRIPTION
1A	2.0	Pick Up Grasp—Small, medium or large object by itself, easily grasped.
1B	3.5	Very small object or object lying close against a flat surface.
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than ½".
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter ¼" to ½".
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than ¼".
2	5.6	Regrasp.
3	5.6	Transfer Grasp.
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 1" x 1" x 1".
4B	9.1	Object jumbled with other objects so search and select occur. ¼" x ¼" x ⅛" to 1" x 1" x 1".
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than ¼" x ¼" x ⅛".
5	0	Contact, sliding or hook grasp.

TABLE V—POSITION*—P

CLASS OF FIT		Symmetry	Easy To Handle	Difficult To Handle
1—Loose	No pressure required	S	5.6	11.2
		SS	9.1	14.7
		NS	10.4	16.0
2—Close	Light pressure required	S	16.2	21.8
		SS	19.7	25.3
		NS	21.0	26.6
3—Exact	Heavy pressure required.	S	43.0	48.6
		SS	46.5	52.1
		NS	47.8	53.4

*Distance moved to engage—1" or less.

TABLE VI—RELEASE—RL

Case	Time TMU	DESCRIPTION
1	2.0	Normal release performed by opening fingers as independent motion.
2	0	Contact Release.

TABLE VII—DISENGAGE—D

CLASS OF FIT	Easy to Handle	Difficult to Handle
1—Loose—Very slight effort, blends with subsequent move.	4.0	5.7
2—Close — Normal effort, slight recoil.	7.5	11.8
3—Tight — Considerable effort, hand recoils markedly.	22.9	34.7

TABLE VIII—EYE TRAVEL TIME AND EYE FOCUS—ET AND EF

Eye Travel Time $=15.2\times\frac{T}{D}$ TMU, with a maximum value of 20 TMU.

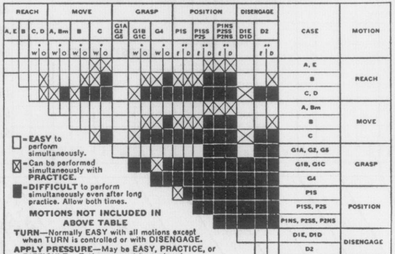
where T = the distance between points from and to which the eye travels.
D = the perpendicular distance from the eye to the line of travel T.

Eye Focus Time = 7.3 TMU.

TABLE IX—BODY, LEG AND FOOT MOTIONS

DESCRIPTION	SYMBOL	DISTANCE	TIME TMU
Foot Motion—Hinged at Ankle.	FM	Up to 4"	8.5
With heavy pressure.	FMP		19.1
Leg or Foreleg Motion.	LM —	Up to 6"	7.1
		Each add'l. inch	1.2
Sidestep—Case 1—Complete when leading leg contacts floor.	SS-C1	Less than 12"	Use REACH or MOVE Time
		12"	17.0
		Each add'l. inch	.6
Case 2—Lagging leg must contact floor before next motion can be made.	SS-C2	12"	34.1
		Each add'l. inch	1.1
Bend, Stoop, or Kneel on One Knee.	B,S,KOK		29.0
Arise.	AB,AS,AKOK		31.9
Kneel on Floor—Both Knees.	KBK		69.4
Arise.	AKBK		76.7
Sit.	SIT		34.7
Stand from Sitting Position.	STD		43.4
Turn Body 45 to 90 degrees— Case 1—Complete when leading leg contacts floor.	TBC1		18.6
Case 2—Lagging leg must contact floor before next motion can be made.	TBC2		37.2
Walk.	W-FT.	Per Foot	5.3
Walk.	W-P	Per Pace	15.0

TABLE X—SIMULTANEOUS MOTIONS



= EASY to perform simultaneously.

= Can be performed simultaneously with PRACTICE.

= DIFFICULT to perform simultaneously even after long practice. Allow both times.

MOTIONS NOT INCLUDED IN ABOVE TABLE

TURN—Normally EASY with all motions except when TURN is controlled or with DISENGAGE.
APPLY PRESSURE—May be EASY, PRACTICE, or DIFFICULT. Each case must be analyzed.
POSITION—Class 3—Always DIFFICULT.
DISENGAGE—Class 3—Normally DIFFICULT.
RELEASE—Always EASY.
DISENGAGE—Any class may be DIFFICULT if care must be exercised to avoid injury or damage to object.

* W = Within the area of normal vision.
O = Outside the area of normal vision.
** E = EASY to handle.
D = DIFFICULT to handle.

SUPPLEMENTARY MTM DATA

Tables 1 and 2 are supplementary data. For proper explanation and usage, refer to MTM Application Training Supplements No. 8 and No. 9.

TABLE 1—POSITION—P (SUPPLEMENTARY DATA)

Class of Fit and Clearance	Case of† Symmetry	Align Only	Depth of Insertion (per ¼") 0	2	4	6
21 .150"—.350"	S	3.0	3.4	6.6	7.7	8.8
	SS	3.0	10.3	13.5	14.6	15.7
	NS	4.8	15.5	18.7	19.8	20.9
22 .025"—.149"	S	7.2	7.2	11.9	13.0	14.2
	SS	8.0	14.9	19.6	20.7	21.9
	NS	9.5	20.2	24.9	26.0	27.2
23* .005"—.024"	S	9.5	9.5	16.3	18.7	21.0
	SS	10.4	17.3	24.1	26.5	28.8
	NS	12.2	22.9	29.7	32.1	34.4

*BINDING—Add observed number of Apply Pressure
DIFFICULT HANDLING—Add observed number of G2.

†Determine symmetry by geometric properties, except use S case when object is oriented prior to preceding Move.

TABLE 2—APPLY PRESSURE—AP (SUPPLEMENTARY DATA)

Apply Force (AF) = 1.0 + (0.3 × lbs.). TMU for up to 10 lb. = 4.0 TMU max. for 10 lb. and over	
Dwell, Minimum (DM) = 4.2 TMU	Release Force (RLF) = 3.0 TMU
AP = AF + Dwell + RLF	APB = AP + G2

MTM ASSOCIATION FOR STANDARDS AND RESEARCH
Huron Towers, 2200 Fuller Road
ANN ARBOR, MICHIGAN

88

TIME STUDY OBSERVATION

DATE 5/10/66

TIME START 8:00 A.M. P.M.

TIME STOP 8:05.54 A.M. P.M.

ELAPSED TIME 5.54"

NUMB. PIECES 10

SHEET NO. ____

NO. SHEETS ____

ELEMENTS:
(1) PICK-UP, LOAD, LOCK, START MACHINE
(2) DRILL ½" THROUGH, FEED KICKS OUT
(3) UNLOCK, UNLOAD, LAY ASIDE, REACH

NOTES	Line	(1) T	(1) R	(2) T	(2) R	(3) T	(3) R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R
	1		.08		.48		.55																						
	2		.64		^{1}.03		.09																						
	3		.19		.60		.67																						
	4		.75		^{2}.15		.22																						
	5		.31		.72		.78			SEE PAGE 54																			
	6		.86		^{3}.26		.33																						
	7		.42		.81		.87																						
	8		.95		^{4}.35		.42																						
	9		.51		.91		.97																						
	10		^{5}.05		.46		.54																						
	11																												
	12																												
	13																												
	14																												
	15																												
	16																												

SUMMARY

	(1)	(2)	(3)											
Total Time														
No. of Readings														
Av. of Readings														
Frequency														
Average Time														
El. Rating Factor														
El. Normal Time														

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A			
B			
C			
D			
E			
F			
G			
H			
I			

Av. Cycle Time ____
Cycle Rating Factor ____
Normal Cycle Time ____

Percent Allowances

Pers.	Fat.	Delay	Total

Std. Time Per Unit ____
Pieces Per Hour ____
Std. Hours Per 100 ____

Allowances in Minutes

Pers.	Fat.	Delay	Total

Avail. Prod. Min. Per Hr. ____
Pieces Per Hour ____
Std. Hrs. Per 100 ____

Work Sheet No. 8

TIME STUDY OBSERVATION

DATE ______

TIME START ______ A.M. P.M. ______

TIME STOP ______ A.M. P.M. ______

ELAPSED TIME ______

NUMB. PIECES ______

SHEET NO. ______

NO. SHEETS ______

NUMBER	ELEMENTS	(1) PICK-UP, LOAD, LOCK, START MACHINE		(2) DRILL ½" THROUGH, FEED KICKS OUT		(3) UNLOCK, UNLOAD, LAY ASIDE, REACH	
NOTES	Line	T	R	T	R	T	R
	1	08	.08	40	.48	07	.55
	2	09	.64	39	[1].03	06	.09
	3	10	.19	41	.60	07	.67
	4	08	.75	40	[2].15	07	.22
	5	09	.31	41	.72	06	.78
	6	08	.86	40	[3].26	07	.33
	7	09	.42	39	.81	06	.87
	8	08	.95	40	[4].35	07	.42
	9	09	.51	40	.91	06	.97
	10	08	[5].05	41	.46	08	.54
	11						
	12						
	13						
	14						
	15						
	16						

SEE PAGE 54

SUMMARY

Total Time			
No. of Readings			
Av. of Readings			
Frequency			
Average Time			
El. Rating Factor			
El. Normal Time			

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A			
B			
C			
D			
E			
F			
G			
H			
I			

Av. Cycle Time ______
Cycle Rating Factor ______
Normal Cycle Time ______

Percent Allowances

Pers.	Fat.	Delay	Total

Std. Time Per Unit ______
Pieces Per Hour ______
Std. Hours Per 100 ______

Allowances in Minutes

Pers.	Fat.	Delay	Total

Avail. Prod. Min. Per Hr. ______
Pieces Per Hour ______
Std. Hrs. Per 100 ______

Work Sheet No. 9

TIME STUDY OBSERVATION

DATE ______
TIME START ______ A.M. P.M. ______
TIME STOP ______ A.M. P.M. ______
ELAPSED TIME ______
NUMB. PIECES ______

SHEET NO. ______
NO. SHEETS ______

ELEMENTS:
(1) PICK-UP, LOAD, LOCK, START MACHINE
(2) DRILL ½" THROUGH, FEED KICKS OUT
(3) UNLOCK, UNLOAD, LAY ASIDE, REACH
(4) INSPECT EVERY 5 PIECES

SEE PAGE 55

NOTES	Line	(1) T	(1) R	(2) T	(2) R	(3) T	(3) R	(4) T	(4) R
	1	08	.08	40	.48	07	.55		
	2	09	.64	39	^{1}.03	06	.09		
	3	10	.19	41	.60	07	.67		
	4	08	.75	40	^{2}.15	07	.22		
	5	09	.31	41	.72	06	.78		
	6	08	.86	40	^{3}.26	07	.33		
	7	09	.42	39	.81	06	.87		
	8	08	.95	40	^{4}.35	07	.42		
	9	09	.51	40	.91	06	.97		
	10	08	^{5}.05	41	.46	08	.54		
	11							33	
	12								
	13								
	14								
	15								
	16							38	

SUMMARY

	(1)	(2)	(3)	(4)
Total Time	.86	4.01	.67	.71
No. of Readings	10	10	10	2
Av. of Readings	.086	.401	.067	.355
Frequency	1/1	1/1	1/1	1/5
Average Time	.086	.401	.067	.071
El. Rating Factor	115	–	110	90
El. Normal Time	.0989	.401	.0737	.0639

SEE PAGES 55-56

SEE PAGES 56-57

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A			
B			
C			
D			
E			
F			
G			
H			
I			

Av. Cycle Time ______
Cycle Rating Factor ______
Normal Cycle Time .6375

Percent Allowances

Pers.	Fat.	Delay	Total

Std. Time Per Unit ______
Pieces Per Hour ______
Std. Hours Per 100 ______

Allowances in Minutes

Pers.	Fat.	Delay	Total
3	3	3	9

Avail. Prod. Min. Per Hr. 51
Pieces Per Hour 79.7
Std. Hrs. Per 100 1.24

Work Sheet No. 10

INTERNATIONAL UNION ALLIED INDUSTRIAL WORKERS OF AMERICA

A I W

CHARTERED AUGUST 26, 1935