APPLICATION OF WORK SAMPLING TO SHORT CYCLE ASSEMBLY OPERATIONS

by

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ABSTRACT

The objective of this work is to study the applicability of work sampling to a short cycle repetitive operation and to compare the economics of work sampling technique with a conventional time study.

To make this comparison, work sampling studies were carried out concurrently with ongoing time studies done by personnel of the Industrial Engineering department in a local lock factory.

The criteria for the study were :

1.- The base data would ensure that the predictions would be within ± five percent of the true value with 95% certainty. These are standard confidence limits for most industrial applications.

2.- Preparation time for work sampling and time study were assumed to be equal.

Two operations were studied, a line assembly operation and a bench assembly operation.

The first study represents the work of a team of four people as a unit. The workers often changed their activities to achieve a better balance of the line, since the nature of the operation is such that it is practically impossible to have the workers at fixed positions performing the same activity all the time.

The second activity represents numerous workers working independently at benches.

The study proved that for assembly operations work sampling can be used to good effect and at viable cost when compared with standard stop watch study. The acceptability of the studies psychologically favours work sampling, as does the level of training required for the time study practitioner. It is generally accepted that a work sampling analyst could be trained in one-quarter of the time which would be required for time study.

Approved by : Prof. N. Eley

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CHAPTER I

INTRODUCTION TO WORK MEASUREMENT

The measurement of human work is an integral part of productivity.

1.1 PRODUCTIVITY

Productivity has been generally defined as:

PRODUCTIVITY = (OUTPUT) / (INPUT)

In principle, this productivity ratio is a simple and straightforward one, but if an attempt is made to apply such a measurement over too large an area then considerable complexity may result. Fairly simple examples may be the number of words typed per minute by a secretary or the number of cubic meters dug by a labourer per day. On the other hand, when productivity is applied to a factory, the input and output would have to be expressed in a common quantification factor. Problems arise in defining this factor. Not only is there difficulty with the evaluation of the input (manpower, materials and capital equipment) in homogeneous units, but also with the evaluation of the output.

There have been several attempts to evaluate the productivity ratio. Smith and Beeching [1] suggested a factor called 'man-year equivalents'. These were obtained by dividing the actual sum of money spent on the resources by the average industrial income at that time. Capital investment would, of course, require a further division by the years of amortization. By adding together equivalent man-years of manpower, materials and capital equipment, an expression of input is derived which takes inflation into account. This sum was called the 'resources-man-years'.

William T. Stewart in his article on productivity[2] describes and gives a practical application of a different 'yardstick' for measuring the elusive productivity concept. Mr. Stewart uses the Keeney model of multiplicate multiattribute utility function, in which a representative management group establishes utility values for various departments to help determine productivity goals.

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[1] Dennis A. Whitmore, WORK MEASUREMENT, (Great Britain, Butler & Tanner Ltd, 1975) p. 2.

[2] William T. Stewart: IE PRODUCTIVITY SERIES, Vol. 10 No. 2 of The Journal of Industrial Engineering (February 1978), p. 58.

This group selects the relevant ratios that affect productivity such as inventory turnover (cost of goods sold/average inventory), value added per direct labour hour, key machine efficiency (a percent that reflects the actual utilization of high investment machines), material identification and location accuracy, total operating quality cost per net sales dollar, and so on.

These factors would depend entirely upon the industry under study. The representative management group would select and decide the number of ratios to take into account.

The ratios are multiplied by the scaling factors (rank) and added together giving what Stewart calls the 'composite productivity utility measure'.

The total productivity is a broad long-term guide to the senior management describing progress of the company. It does not point out the specific areas that may need corrective action.

This leads us to the next section in which an attempt is made to subdivide productivity.

1.2 MANAGEMENT RATIOS

This is another way of measuring productivity. They are financial ratios rather than measurements related to a defined yardstick such as the 'man-year'.

Dun & Bradstreet publishes the 'Key Business Ratios in Canada', a yearly compilation of over 150 lines of retailing, wholesaling, manufacturing and construction businesses. Examples of these ratios might be:

$$\frac{\text{PROFIT}}{\text{SALES}}$$

$$\frac{\text{SALES}}{\text{TANGIBLE NET WORTH}}$$

$$\frac{\text{SALES}}{\text{INVENTORY}}$$

It has been claimed that management ratios derived in this way can be used to compare the 'state of health' of different companies in the same line of business.

From the above discussion, it becomes clear that in most manufacturing companies, the concept of productivity measurement is a complex one.

1.3 DIRECT MEANS OF IMPROVING PRODUCTIVITY.

Against this general background, it is now possible to define work measurement and understand its importance.

Generally speaking, productivity can almost always be increased by heavy investment of money in new and improved plants or equipment. This rise in productivity usually takes time in planning, searching, implementing and testing.

On the other hand, an increase in productivity can also be obtained by reducing wasted human effort and time in operating the manufacturing process or eliminating unnecessary movements.

The systematic approach of reducing the work content of the manufacturing process is called method study, and the technique of locating ineffective time and setting standards of performance is called work measurement.

The formal definitions are: [1]

'Method study is the systematic recording and critical examination of existing and proposed methods of doing work, as a means of developing and applying easier and more effective methods and reducing cost'[2]

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

Method study and work measurement are closely linked. Method study simplifies the job and develops more economical ways of doing it, while work

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[1] These definitions were adopted from: International Labor Office: INTRODUCTION TO WORK STUDY REVISED EDITION (Switzerland, Impression Coleurs Weber, 1974), Appendix 5, p. 413 - 424.

measurement is concerned with the determination of how long it should take to do the job.

Work measurement provides the management with a means of measuring the time taken to perform the operations in such a way that the ineffective time will show up and can then be separated from the effective time.

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

CHAPTER II

TECHNIQUES OF WORK MEASUREMENT

The existing techniques of work measurement are briefly described in this chapter.

Before outlining the techniques of work measurement, the following terms should be defined : [1]

2.1 TERMS USED IN WORK MEASUREMENT

Observed Time .- The time taken to perform an element or combination of elements obtained by means of direct measurement.

Element .- A distinct part of a specified job selected for convenience of observation, measurement and analysis.

Standard Performance or Standard Pace .- The rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift provided they know and adhere to the specified method and provided they are motivated to apply themselves to their work. This performance is denoted as 100 on the standard rating.

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[1] These definitions were adopted from: International Labor Office: INTRODUCTION TO WORK STUDY REVISED EDITION (Switzerland, Impression Coleurs Weber, 1974), Appendix 5, p. 413 - 424.

Rating .- The assessment of the worker's rate of working relative to the observer's concept of the rate corresponding to standard pace.

Basic Time or Normal Time .- The time for carrying out an element of work at standard rating, i.e.-

$$\frac{\text{Observed Time x Observed Rating}}{\text{Standard Rating}}$$

Standard Time .- The total time in which a job should be completed at standard performance, i.e. work content, relaxation allowances, unoccupied time and interference allowances, where applicable.

Relaxation Allowances .- An addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of allowance will depend on the nature of the job.

The available techniques may be divided into three major groups : stop-watch time study, statistical standards (work sampling) and predetermined motion time system.

Stop-watch time study is a technique for recording the times and rates for working for the elements of a specified job carried out under specified conditions, and for analysing the data to obtain the time necessary for carrying out the job at a defined level of performance.

Statistical standards or work sampling, is a technique in which a large number of instantaneous observations are made over a period of time of a group of machines, manufacturing processes or workers. Each observation records what is happening at that instant and the percentage of observations recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs.

Stop-watch and work sampling involve the measurement of actual observed time and its adjustment to obtain normal time by means of performance rating.

Predetermined Motion Time System is a technique whereby times established for basic human motions (classified according to the nature of the motion and the conditions under which it is made) are used to build up the time for a job at a defined level of performance.

2.2 STOP-WATCH TIME STUDY

The 'Survey of Work Measurement and Wage Incentives'[1] carried out by Robert S. Rice in collaboration with Patton Consultants and A.I.I.E. showed that the most prevalent approach to work measurement currently used by American and Canadian industries involves a stop watch time study and simultaneous performance rating of the operation to determine normal time.

The procedure involves the following steps.

1.- Recording the standard method and identifying the unit of work. The following items are generally included :

a) The department in which the job is performed.

b) Job number.

c) Product, material specifications, and identification as related to the operation.

d) Work place layout and dimensions.

e) Tool descriptions.

f) Feeds and speeds of machines.

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[1] Rice R. : SURVEY OF WORK MEASUREMENT AND WAGE INCENTIVES, Vol. No. 7 of The Journal of Industrial Engineering, (July 1977), p. 18

2.- Selecting the operator for the study. He has to be experienced and trained in the standard method.

3.- Determining the elemental structure of the operation for timing purposes. The criterion to be followed is that end points have to be easily detected and defined.

4.- Observing and recording the time required for each element. During the observations, the worker is being rated.

5.- Determining the number of cycles to study. This number depends on the duration of the basic time of the cycle, and on the dispersion of the basic times obtained during the study. A common practice is to take ten readings initially of basic time cycles, and from these readings calculate the number of cycles to study. (This topic will be covered in the next section).

6.- Computing normal time = average observed time x average rating factor/100

7.- Determining standard time = normal time(1 + allowances in percent)

2.3 REPRESENTATIVE SAMPLES OF TIMES

Some variation in the cycle time almost always occurs, even if the worker under observation is not attempting to vary his pace. This could be due to the random variation in the operator's pace, position of the parts worked with, position of the tools used, or simply variation caused by slight errors by the time study person in timing the worker.

A reasonable limit in the number of readings is to take enough to make the chances 95 out of 100 that the observed average time will be ± 5 per cent of the true average [1]. This is called in Statistics 95 per cent confidence with ± 5 per cent of the standard error of the mean.

This criterion has proved to be accurate enough if time studies are going to be used for establishing incentive wages, since ± 5 per cent of the standard usually approximates a bargainable increment in wages.[2]

The sampling theory involves basically two formulae, Eqs. 2.1 and 2.2. Both are based on the

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[1] True average is defined as the average value that a time study person would find if he were to spend his life timing the worker.

[2] Mundel M. : HANDBOOK OF INDUSTRIAL ENGINEERING AND MANAGEMENT, SECOND EDITION, Prentice-Hall, 1971, p. 267.

assumption that random causes are controlling the length of time of the cycle. In most cases, this is a reasonable assumption [1].

$$S = \{ \sqrt{N \Sigma X^2 - (\Sigma X)^2} \} / N \qquad (2.1)$$

WHERE :

S = Standard deviation.

X = Rated individual readings.

Σ = Sum of homogeneous elements.

N = Number of readings of an element.

The standard error of the mean Sx indicates the probable variability of the averages of groups of N values of X about the obtained mean or average of all readings of an element. It can be computed by Eq. 2.2.

$$Sx = S / \sqrt{N} \qquad (2.2)$$

The property of this last measure is such that 95 per cent[2] of the probable values of the average for the element will lie within $\pm$ 2Sx of the true average.

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[1] These equations are derived and explained in Appendix A.

[2] Actually 95.4 per cent, but it is usually rounded off to 95.

Therefore, if 2Sx is less than or equal to 5 per cent of the mean value, it may be said that the chances are at least 95 out of 100 that the average for the element is within ± 5 per cent of the true average.

Eqs. 2.1 and 2.2 are combined, and ± 2Sx is set equal to 5 per cent of the mean value. The final equation 2.3 is solved for the number of readings N' required to ensure 95 per cent certainty that the obtained average reading will be within ± 5 per cent of the true average cycle.

$$N' = \left\{ \frac{40 \sqrt{N \sum X^2 - (\sum X)^2}}{(\sum X)^2} \right\}^2 \qquad (2.3)$$

Where :

N' = Number of readings needed computed from N.

N = Number of cycles or readings taken at the time of computing N'.

This equation is easily translated into instructions for a portable programmable calculator.[1]

2.4 RATING

In recent studies the rating factor has proved to play an important role in obtaining the standard time.

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[1]A programme for a Hewlett Packard Calculator model 25 is found in Appendix B.

Rating is that process during which the time-study analyst compares the performance (speed or tempo) of the operator under observation with the observer's own concept of normal performance.

Rating is a matter of judgment on the part of the time-study analyst, and unfortunately judgement is an indispensable factor in setting a time standard for an operation.

Since rating is a subjective judgment entering the computation of the time standard, the immediate question that comes to mind is : "How accurately can experienced people rate?". Controlled studies, in which films from different industries showed workers performing at different rates, proved that experienced analysts could come to an agreement in rating within ± 3 per cent [1].

2.5 DETERMINING THE NUMBER OF READINGS A PRACTICAL APPLICATION

Consider the time study carried out in one of the local manufacturing firms.

In this case, the cycle time was taken as one single element, due to the short elapsed time of the

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[1] Buffa E. : MODERN PRODUCTION MANAGEMENT, (New York, John Wiley & sons, 1973) p. 423.

constituent elements.

The rating was posted as 100, since according to the time study man the worker under observation was performing at normal pace.

The first ten readings in minutes were:

.28 .35 .24 .31 .25 .25 .28 .26 .25 .28

Applying the Eq. 2.3 or making use of the programme mentioned above, the first estimate of the necessary number of readings is obtained:

$$N' = 22 \text{ Readings},$$

and, Average reading = .283 Minutes.

More data were obtained. After each reading, the number of required cycles was found using a portable programmable calculator. ***

In this case, 20 readings were enough to be included within the 95 % confidence limits within ± 5 % of the true mean. The average reading was .271 min.

This average reading is called 'observed time'.

The normal time is found by applying the following equation :

$$\text{NORMAL TIME} = \{ \text{ OBSERVED TIME } \} \times \{ \text{ RATING } \} \qquad (2.4)$$

In this case, the analyst rated the operator at

*** See Appendix C

100 %, so the normal time and the observed time were equal.

2.6 DETERMINING PRODUCTION STANDARDS

The standard time is found by applying the following equation which includes the personal and fatigue allowances.

STANDARD TIME = NORMAL TIME(1+RELAXATION ALLOWANCES) (2.5)

In this case :

Standard Time = .271 x 1.15 = .312 min. or

STANDARD OUTPUT = 192 Parts/hour.

CHAPTER III

WORK SAMPLING

3.1 INTRODUCTION

Work sampling is a method commonly used to estimate the portion of time that an activity occurs, without necessitating continuous observation. It is a fact finding method based on the laws of probability, especially the bincmial distribution.

The first article describing work sampling, kncwn at that time as the 'Snap Reading Method', was published by L.H.C. Tippet in 1935. Work sampling is also called activity sampling, ratio delay method, and random observation method.

Work sampling has the following uses :

1.- Ratio delay .- To evaluate the activities and delays of man or machine.

2.- Performance sampling .- Same as ratio delay including a rating factor during the productive portion.

3.- Establishment of standard time .- In scme studies where the output and the elapsed time of the study are recorded, it is possible to estimate the standard time.

In this paper work sampling is used to establish standard times since both the output and the time at which the sampling is done are kept for further computations.

Work sampling is based upon the laws of probability. A sample randomly taken from a population tends to follow the same pattern of distribution as the population. If the sample is large enough, the characteristics of the sample will differ little from the characteristics of the group. Moreover, it is possible to predict the accuracy of the difference with a degree of certainty .

3.2 AN EXAMPLE OF SAMPLING.

Suppose we want to estimate the proportion of time that a worker, or group of workers, spend working and not working. This could be accomplished by long term stop-watch studies in which either the productive or non-productive times are recorded.

This is a lengthy and consequently costly approach. Instead, suppose that a large number of observations are taken at random times. The outcome of an observation would be : whether the operator is working or idle and then the observer would tally the results. This tally is shown in the following figure.

	TALLY	NUMBER	PER CENT
WORKING	//// //	98	93.33
IDLE	//// ///	7	6.67
TOTAL		105	100.00

Figure 3.1

Work Sampling Tally of Working and Idle Time.

The percentages of the tallies under working and idle classifications are estimates of the actual percentage of time that the worker was working and idle. Herein lies the fundamental principle behind work sampling :

"The number of observations is proportional to the amount of time spent in the working or idle state."[1]

3.3 CONFIDENCE LEVEL.

The statistical principles of work sampling depend upon the binomial distribution as the outcome of an observation is either working or idle; success or failure .

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[1] Buffa E. : MODERN PRODUCTION MANAGEMENT, New York, John Wiley & sons, 1973 p. 431.

Such distribution is identified by:

$$p = \frac{X}{N} = \frac{\text{NUMBER OBSERVED IN CLASSIFICATION}}{\text{TOTAL NUMBER OF OBSERVATIONS}} \quad (3.1)$$

And

$$\text{Sigma} = \sqrt{p(1-p)/N} \quad (3.2)$$

Where :

p = Portion of time that the worker was found working.

N = Total Number of Observations

Sigma = Standard Deviation

It is necessary to determine what level of confidence is desired in the final results. The most common confidence interval is 95.45%, which is usually rounded off to 95%.

This concept can be visualized as the area under a normal distribution within the limits ± 2 Sigma .

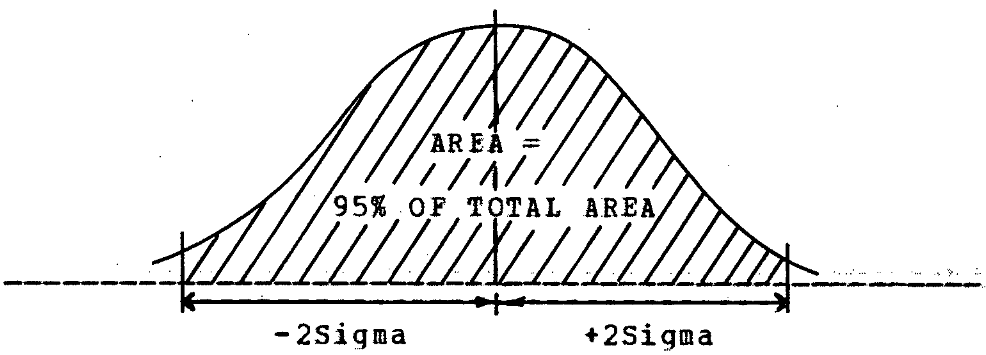


Figure 3.2

3.4 ACCURACY OF WORK SAMPLING

The accuracy achieved in work sampling is affected by the number of observations. The purpose of the study will determine the number of observations required.

The analyst can always estimate the number of observations from previous experiences or from a pilot study. One of the things the analyst must always keep in mind is the inherent variability of the people, machines or processes being measured. In some cases the output of a department may present an ideal situation for work sampling with raw material of reasonably uniform quality, low labor turnover, and good supervision. At other times the situation may not be as favorable, and in such cases the experience of the analyst plays an important role in the study.

For many kinds of measurements an accuracy of ± 5% is considered satisfactory.

Assuming that the binomial distribution is used as a basis for determining the error, the number of observations required for 95% of confidence can be found taking ± 2 sigma :

$$Sp = 2 \left[\sqrt{p(1-p)/N} \right] \qquad (3.3)$$

Where :

S = relative accuracy ($\pm$ 5%)

p = percentage occurrence of an activity

N = total number of random observations

The relative accuracy is a term commonly used in industry, and is defined as the ratio of standard deviation to the number of readings.

From this expression, it is clear that even if the desired accuracy is known, there are two variables: p, the percentage occurrence, and N, the total number of random observations. In order to find N, p is generally assumed or estimated from a pilot study.

3.5 EXAMPLE OF ACCURACY

Suppose we want to determine the percentage of productive time of a worker in the department of latch assembly by work sampling.

Suppose that 105 observations were taken at random times, and that 7 times the operator was either idle or out of the working area.

Then the percentage of the productive time would be 93.33% (98 / 105 x 100 = 93.33%)

And now N can be calculated, knowing that p = .933 and S = $\pm$ .05.

$$Sp = 2 \left[\sqrt{\frac{p\,(1-p)}{N}} \right]$$

$$.05p = 2 \left[\sqrt{\frac{p\,(1-p)}{N}} \right]$$

$$N = \frac{4p\,(1-p)}{.0025p^2} = \frac{1600\,(1-p)}{p} \qquad (3.4)$$

In this case :

$$N = \frac{1600\,(1-.933)}{.933} = 115 \text{ Observations}$$

3.6 ACCURACY FOR A GIVEN NUMBER OF OBSERVATIONS.

In practice, the work sampling man covers several stations during his study, and most likely the percentages will not be the same for the different stations.

The previous equation can be solved for the relative accuracy S, given the percentage p and the total number of observations N.

Continuing with the above example where p = 93.3% and N = 105.

$$S = \frac{2}{p}\sqrt{\frac{p\,(1-p)}{N}}$$

$$S = \frac{2}{.933}\sqrt{\frac{.933(1-.933)}{105}}$$

$$S = \pm .052$$

In this case , it could be said that we are 95% confident that the operator under observation in the latch-assembly area was working 93.3% of the time within an accuracy of our estimate of ± 5.2% of 93.3%

(5.2% x 93.3% = 4.87%), or the true value was between 98.17% and 88.43%, having as a most probable value 93.3%.

3.7 DETERMINING PRODUCTION STANDARDS.

Having found an estimate for the proportion of time that the worker spent doing productive activity, the following step is to compute the normal time.

In doing so, the total time of the study in minutes is required. This time excludes scheduled delays such as coffee breaks, lunch time and clean-up time. Let us say that the 105 observations were made during a day . There is a 15 minute coffee-break in the morning and a 12 minute coffee-break in the afternoon. Lunch takes 30 min and clean-up time is 5 min.

Adding up all these scheduled delays, it comes out to:

First Coffee-Break	15 min.
Lunch Time	30 min
Second Coffee-Break	12 min
Clean-up Time	5 min.
Total Scheduled Delays	62 min.

Working hours are from 7:30 to 16:00 . That means workers spend 8.50 hours or 510 minutes in the factory.

Subtracting the scheduled delays (62 min.) from the time the worker spends in the factory (510 min.) gives us the total available time for production which is 510 - 62 = 448 min.

Another factor required in our computation is the average rating. In this case, the average performance rating was 102%, that means that for the analyst, the worker under observation was performing slightly above normal performance.

Finally the output from this bench was 855 latches for the day.

With this information, the normal time is computed from the following expression: (3.5)

$$\text{NORMAL TIME} = \frac{\begin{matrix}\text{TOTAL TIME} \\ \text{OF STUDY} \\ \text{IN MINUTES}\end{matrix} \times \begin{matrix}\text{PRODUCTIVE} \\ \text{PERCENTAGE} \\ \text{FROM W.S.}\end{matrix} \times \begin{matrix}\text{AVERAGE} \\ \text{PERFORMANCE} \\ \text{RATING}\end{matrix}}{\text{TOTAL NUMBER OF PIECES PRODUCED}}$$

Applying this equation to the data mentioned above:

$$\text{Normal time} = \frac{\overset{\text{(Time)}}{448} \times \overset{\text{(Percentage)}}{.933} \times \overset{\text{(Rating)}}{1.02}}{\underset{\text{(Output)}}{855}}$$

Normal time = .50 Min.

The standard time is calculated from the normal time and the allowances for delays, fatigue, and personal time. In this department such allowances are 15%.

Placing these numbers in the following expression:

STANDARD TIME = (NORMAL TIME) X (1 + ALLOWANCES) (3.6)

It results:

Standard time = (.50)x(1+ .15)

<u>Standard time = 0.57 min/latch</u>

Some manufacturing industries express their standards in terms of pieces/hour for accounting purposes.

In this case the output rate is:

(60min/hour)*(0.57min/latch) = 104 latches/hour.

CHAPTER IV

APPLICATIONS OF COMPUTERS TO WORK SAMPLING

4.1 INTRODUCTION

The work sampling studies which are the subject of this thesis were carried out in a local manufacturing plant, whose main products are domestic and security locks.

Some of the constituent parts of the lock are made in the lock company, other parts are supplied by local firms and the rest come from branch plants, which are spread all over the world.

The work sampling studies were done with the total cooperation of the personnel of the company, from the General Manager, the Industrial Engineering department, to the workers, who voluntarily agreed to take an active part in this study.

The study presented in this chapter was done in the packing department.

In this department the parts are supplied by indirect labour to the packing line which is attended by four operators.

4.2 DESCRIPTION OF THE LINE

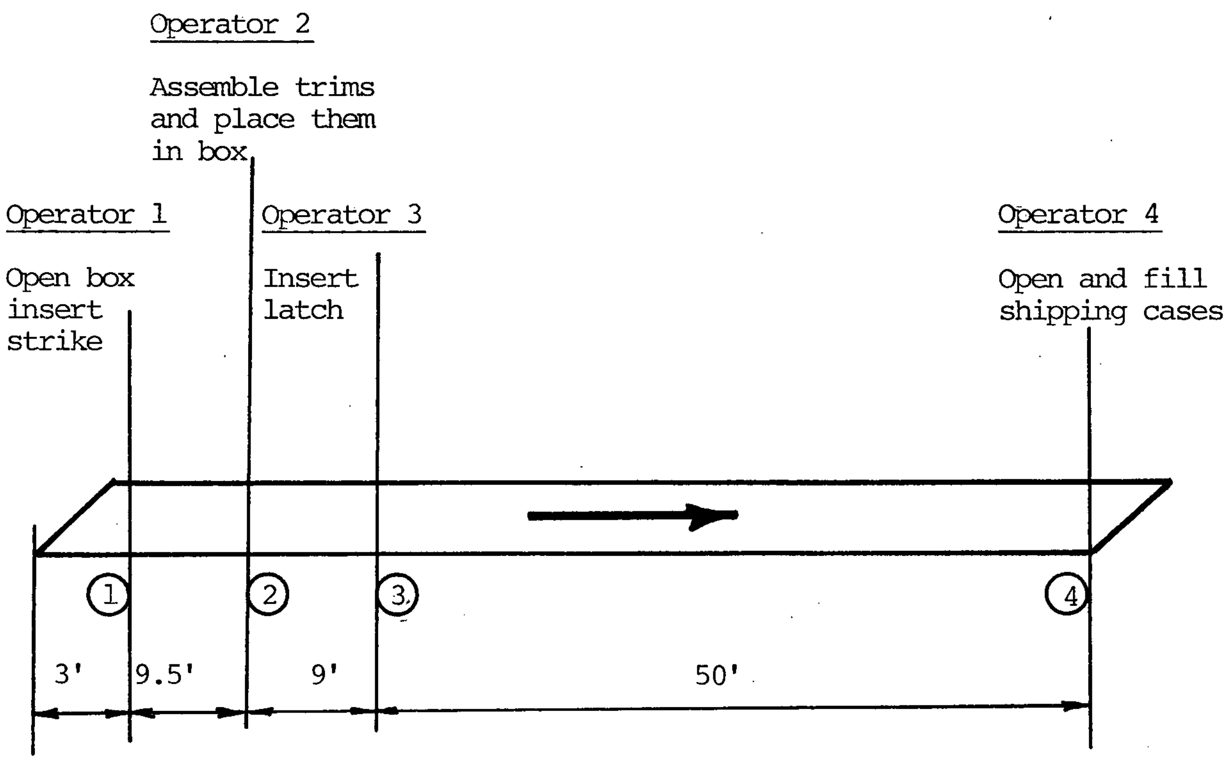
A diagram of the line is found in Fig. 4.1. In the first station (Fig. 4.2), the operator opens the box in batches of ten or fifteen and places them on a moving belt. The same operator (Fig. 4.3) is in charge of inserting a small piece (strike) before the boxes arrive at the next station.

The next operator gets the parts from an overhead conveyor in sets of two wooden boxes. She takes the outer trim from one of the wooden boxes, the inner trim from the other (Fig. 4.4A), puts them together (Fig. 4.4B) and places them in the box (Fig. 4.4C).

The third operator (Fig. 4.5) inserts the latch and screw package and closes the box.

The last operator (Figs. 4.6 and 4.7) is in charge of opening and filling the shipping cases.

These four operators do not remain doing the same activity all the time, but they change their places in order to achieve a better balance.



The numbers denote the operators

DIAGRAM OF THE PACKING LINE

Figure 4.1

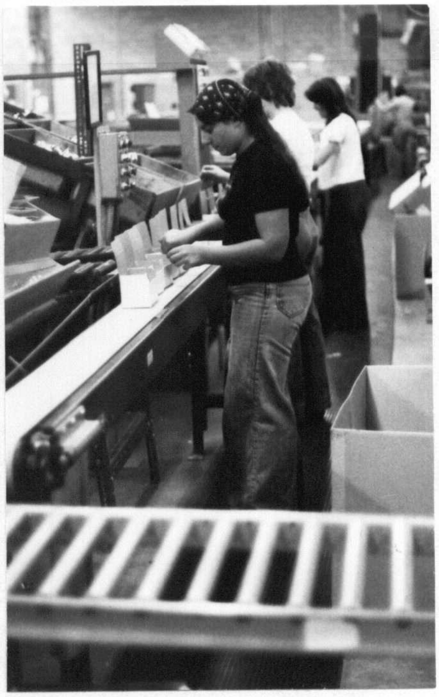
The activity codes will be described in the following sections. They are presented here for convenience.

These activities are illustrated in the following set of pictures.

1 .- Open or make box.

Activity Code 11

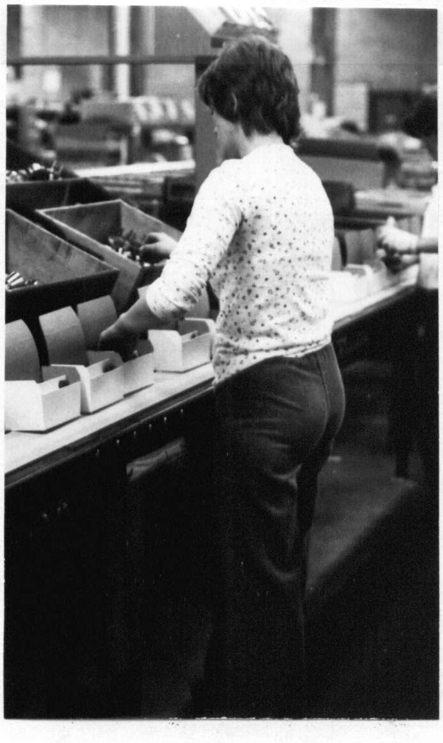
Figure 4.2



2 .- Place parts in box.

Activity Code 12

Figure 4.3



³ Insert inner and outer trim and place them in box.

Activity Code 13

Figure 4.4

4 .- Insert latch.

Activity Code 12

Figure 4.5

5 .- Close the box.

Activity Code 14

Figure 4.6

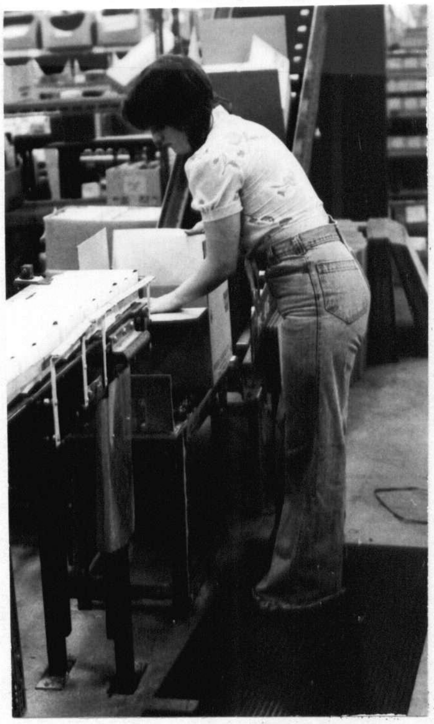
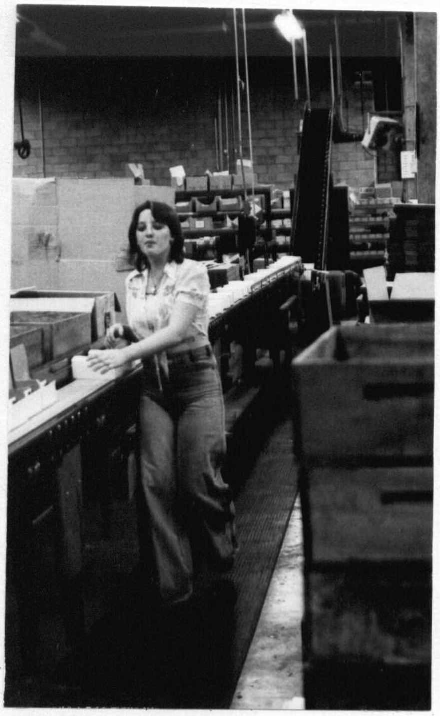


Figure 4.7 [5] open or fill shipping cases, place them on belt. Activity Code 15.



[6] Remove empty boxes, prepare material. Activity Code 21. Figure 4.8

[7] Walking from stations Activity Code 22 Figure 4.9

4.3 THE STUDY

As a first attempt, a standard work sampling form depicted in Fig. 3.1 was used.

During the study, it was felt that a refinement in the form of presentation of the information was highly desirable, since it would not only show whether the operator is working or idle, but it would also classify the working or idle activity.[1] This was particularly applicable to the packing line, since there was a lot of walking involved between stations.

In order to classify all activities that any of the four workers could be found performing, the line was observed during the packing of a lock called A-151. The activities were divided as follows.

---

[1] This form is found in Appendix B.

1.- Open box.	
2.- Insert strike.	
3.- Assemble outer and inner trim,	W
place them in box.	O
4.- Insert latch	R
5.- Fill shipping case.	K
close box.	I
6.- Prepare material,	N
remove empty boxes.	G
7.- Walk from stations.	
8.- Wait for parts.	I
9.- Pick up parts from floor.	D
10.- Out of working area.	L
11.- Converse.	E

Table 4.1 Classification of activities .

In this case, there are 11 different activities which can be classified as productive or non-productive. Activities 1 to 7 represent the working activity, whereas activities 8 to 11 are non-working.

It must be noted that 'walking' was considered to be productive since it was a necessary activity in the line.

It is customary in this kind of study, to use a table of random numbers or random times. In this preliminary study, a programme was written for a

Hewlett Packard Calculator that generates random times between working hours excluding scheduled delays (coffee-breaks and lunch time)[1].

A pilot work sampling study was carried out using the improved recording forms and the random times generated by a programmable calculator.

The operators were observed sequentially. The operator in Fig. 4.2 was first, the operator in Fig. 4.3 was second, the operator in Fig. 4.4 was third and finally the operator in Fig. 4.5 was fourth. It must be noted that the sequence refers to the operators, not to the stations, since as it was stated before, the operators did not remain at a fixed position.

The results from this preliminary study are as follows.

---

[1] The programme and a sample sheet for recording the random times for observations are found in Appendix B

ACTIVITY	NO. OF OBSERVATIONS	PERCENTAGE	ACCUMULATIVE PERCENTAGE
1 Open box.	9	8.1	8.1
2 Insert strike.	6	5.4	13.5
3 Assemble trims & place in box.	36	32.4	45.9
4 Insert latch, screw packs.	7	6.3	52.3
5 Fill shipping case, close box.	21	18.9	71.2
6 Prepare material, remove empty boxes.	2	1.8	73.0
7 Walk.	13	11.7	84.7
WORKING TOTAL.	94		84.7
8 Wait for parts.	0	0.0	0.0
9 Pick up parts from the floor.	2	1.8	1.8
10 Out of area.	13	11.7	13.5
11 Converse.	2	1.8	15.3
IDLE TOTAL.	17		15.3

Table 4.2 Preliminary study of the packing line.

The total number of observations was 111.

The output during the study was 82 shipping cases. Each shipping case contains 24 locks, so the output was 1968 locks.

The total length of the study was 2 hr. 31 min. or 151 min.

Note the high percentage of total observations that represents activity 7, 'Walking'. The study could be further divided into 'walking' and 'not-walking'. This new classification allows us to apply the principle of the binomial distribution (see Chapter 3) and to set probability limits in our findings. The same reasoning could be applied to each activity.

The operators were not rated during the study. They were considered to be working at a normal pace.

The number of readings required for ± 5% is computed from Eq. 3.6

$$N' = 1600 \times (1 - .847) / .847$$

$$N' = 289 \text{ Observations.}$$

More observations were taken to satisfy the above condition, obtaining the following values :

Percentage = .870

Output = 223 Shipping cases = 5352 locks.

Time of study = 400 min.

By applying Eq. 3.7 and taking rating equals to 100%, we obtain :

Normal time = 400 min. x .870 / 5352 locks

Normal time = .06 min./lock or 923 locks/hr.

The personal and fatigue allowances for this department are 15 %. By applying Eq. 3.8, the standard time is :

Standard time = (.06) x (1 + .15) = .07 min. / lock.

or <u>Standard output = 802 locks / hr.</u>

This standard is for the packing of the lock A-151 when the line is attended by four workers.

The relative accuracy is found using Eq. 3.5

$$S = \{ 2 / .870 \} \times \{ \sqrt{.870 \times (1 - .847)/295} \}$$

$$S = \pm 4.5 \text{ for } 95\% \text{ certainty.}$$

During the study, the analyst observed the different paces of the workers, and found that the improved form for recording the information was inappropriate for keeping track of these variations[1]. Moreover, it was noted that the operators' paces were not consistent.

4.4 RATING IN WORK SAMPLING.

A different procedure for recording the observations had to be devised in order to include the rating factor. Two records were required for each activity classified as working (see Table 4.1). One for the number of observations and another for the rating. For activities classified as 'Idle', only a record for the number of observations was needed.

---

[1] See form in Appendix B

To illustrate this, suppose that the analyst recorded the following ratings while observing a worker performing the activity number 5, FILLING SHIPPING CASES AND CLOSING BOXES (see Table 4.1).

90 90 100 90 80 100 90 80 100 90 110 110 90 90 110 100 110 90 100 110 90

The number of observations was 21, which represents 18.9 % of the total observations. The average rating would be the sum of the ratings divided by the number of observations in this category.

AVERAGE RATING = $\sum$ RATINGS/NO. RATED OBSERVATIONS (4.1)

In this case

AVERAGE RATING = 2021 / 21 = 96.2

The rated percentage could be easily evaluated from the following expression :

RATED PERCENTAGE = AVERAGE RATING X PERCENTAGE (4.2)

In the case of this preliminary study for activity 5, we have :

Rated percentage = 96.19/100 x 18.9 = 18.18 %

At this point in time, it was becoming slightly difficult and tedious to keep separate records of the activities and the ratings. Moreover, since work sampling was intended to be used in different departments, new records for the job number and department number were required.

A computer programme was thought to be a suitable solution for the manipulation and processing of the data, since basically what we have here is numerous records that can easily be translated into arrays. The computations themselves are fairly straightforward.

4.5 SCHMID'S COMPUTER PROGRAMME.

Before launching into the development of this programme, a review of the publications in this field was carried out.

It was found that Schmid's computer programme appeared to be similar and compatible with the ideas presented in this thesis[1].

Schmid's computer programme is one of the latest publications of a high caliber in work sampling. Thus, to avoid unnecessary repetition, the use of this programme seemed more logical than the development of a new one.

Except for the slight modifications and necessary adaptations to the existing computing facilities at U.B.C. (because the programme was originally written for a Model 1130 Computer), this programme remains as designed by Dr. Schmid.

---

[1] Schmid M. : WORK MEASUREMENT SAMPLING, University of Dayton, 1970.

For identification purposes, Dr. Schmid makes a further subdivision of 'working', that is production and production-support. Idle is called non-productive.

Productive activities are given codes starting with 11. Production-support activities begin with 21, and non-productive activities start with 31. During the computations, the computer distinguishes only two major categories. Activities whose numbers are less than 30 are 'working' and activities whose numbers are greater than 30 are 'idle' (see Table 4.3).

The computer programme holds up to 1000 observations in a single run. It has several arrays to keep track of the number of observations and the rating for each activity. It applies Eq. 4.1 to find the average rating for each activity, then uses Eq. 4.2 to find the rated percentage. During the calculations, the programme checks for non-productive activities (whose codes are greater than 30). If the search is successful, that activity is rated zero. The total rated activity is the sum of all rated percentages.

$$\text{TOTAL RATED ACTIVITY} = \sum \text{RATED PERCENTAGE} \qquad (4.3)$$

Where :

RATED PERCENTAGE = 0, for activity whose code is greater than 30.

This new classification is shown on the following page.

DEPARTMENT 49 - PACKING

ACTIVITY CODES

Activity Code No.	Significance
Production	
11	Open or make box, put on labels.
12	Place parts in box.
13	Insert inner and outer trim and place them in box.
14	Close box or put on lid, apply transparent tape.
15	Open or fill shipping case, place it on belt.
Production support	
21	Remove empty boxes, prepare material.
22	Walk.
Non-productive	
31	Wait for parts or release stuck wooden boxes.
32	Pick up parts from floor.
33	Absent, personal time.
34	Talk.

Table 4.3

From the above table, it can be seen that the activity codes describe all possible activities that the worker can be found performing.

This breaking down of the activities into three major groups; (production, production support and non-productive) is done by the analyst to achieve a better understanding of the balance of the assembly line (in this particular case packing locks), since for calculation purposes, the computer treats all these 11 activities in two major groups. One comprises all productive and production support activities, and the other includes non-productive activities.

This classification into two groups leads us once more to having two conditions as in the case of the previous chapter (working or idle, success or failure). That is why, although there are 11 activities, the binomial distribution is still applicable.

This computer programme has provisions for keeping track of the times at which observations are made. It also takes as input parameters the starting and finishing of the shift times, and the starting and length of the scheduled delays (coffee-breaks and lunch time). With this information, the effective time of the study is calculated according to the following expression :

$$\text{TOTAL TIME STUDY} = \text{LENGTH OF THE STUDY} - \text{SCHEDULED DELAYS} \qquad (4.4)$$

Finally, knowing the number of pieces produced, the normal time is calculated by applying Eq. 3.7.

It must be noted that the product of 'PRODUCTIVE PERCENTAGE FROM W.S. X AVERAGE PERFORMANCE RATING' has been called TOTAL RATED ACTIVITY (see Eq. 4.3), so this equation becomes

$$\text{NORMAL TIME} = \frac{\text{TOTAL TIME OF STUDY IN MINUTES} \times \text{TOTAL RATED ACTIVITY}}{\text{TOTAL NUMBER OF PIECES PRODUCED}} \qquad (4.5)$$

The standard time is found by applying Eq. 3.8.

The computer programme has eight more records or arrays. They are used for the department, operator, job, special, interruption, day, shift numbers, and the size of the lot.

4.6 RANDOM TIMES FOR OBSERVATIONS.

Work sampling requires that each individual moment have an equal likelihood of being chosen. In order to be statistically acceptable, the observations must be random, unbiased, and independent. A table of random numbers is commonly used in this type of study to ensure the randomness of the times at which the observations are made.

In this paper, a computer programme was developed to generate random times during working hours excluding scheduled delays. This programme uses a function called RAND for generating random numbers.

RAND is a function subprogramme written in /360 assembly language and callable from FORTRAN. This subroutine generates random numbers X, such as $0 \leq X < 1$ under uniform distribution. It has a period of 2^{30}, and has proved to meet the stochastic properties.+++

The random times are printed out in a format suitable for recording the observations.

This programme and a run for two positions or stations are depicted in Appendix D.

From the observation sheet (see Appendix D), the eight arrays that were mentioned in the previous section are as follow:

DEP NUM stands for department number, OPR NUM stands for operator or worker number, JOB NUMBER means the piece number or the assembly number.

The SPECial and INTERruption codes are used when the operator stops or starts a particular job. They are also used when the operator shifts his position. These numbers are seldom used.

+++ See "UBC RANDOM" Write-Up, April 1975

For the worker, Activity Code and Production RaTe were described in previous sections of this chapter.

DAY-NUMber shall be used to keep track of the length of the study. The SHIFT number was 1 for all cases in this paper, and the LOT-SIZe has to be posted only once.

4.7 A PRACTICAL APPLICATION OF SCHMID'S PROGRAMME

Using observation sheets like the ones mentioned above, a pilot work sampling study was carried out on the belt. In this case, the observations were taken when the operators were packing locks type A-151.

The observations are shown in the following three pages.

PAGE NO. 1

LINE	TIME HR	TIME MN	TIME SC	IDENTIFICATION DEP NUM	IDENTIFICATION OPR NUM	IDENTIFICATION JOB NUMBER	SPEC	INTER	WORKER A C	WORKER P RT	DAY NUM	SHIFT	LOT SIZ
1	13	42	30	49	44		8				1	1	
2	13	47	50	49	44	151			21		1	1	
3	13	50	0	49	44	151			21		1	1	
4	13	59	30	49	44	151			15	110	1	1	
5	14	2	40	49	44	151			34		1	1	
6	14	3	40	49	44	151			14		1	1	
7	14	4	50	49	44	151			14	070	1	1	
8	14	5	20	49	44	151			33		1	1	
9	14	6	10	49	44	151			14	085	1	1	
10	14	6	50	49	44	151			33		1	1	
11	14	7	0	49	44	151			14	085	1	1	
12	14	8	30	49	44	151			34		1	1	
13	14	9	0	49	44	151			13	090	1	1	
14	14	10	40	49	44	151			14		1	1	
15	14	11	50	49	44	151			14	075	1	1	
16	14	12	0	49	44	151			14	110	1	1	
17	14	12	10	49	44	151			13	095	1	1	
18	14	12	20	49	44	151			33		1	1	
19	14	12	40	49	44	151			14	080	1	1	
20	14	15	10	49	44	151			15	110	1	1	
21	14	15	30	49	44	151			11		1	1	
22	14	16	10	49	44	151			14	070	1	1	
23	14	20	20	49	44	151			14	070	1	1	
24	14	21	0	49	44	151			14	110	1	1	
25	14	22	50	49	44	151			13	095	1	1	
26	14	24	0	49	44	151			14	095	1	1	
27	14	29	10	49	44	151			14	075	1	1	
28	14	29	20	49	44	151			33		1	1	
29	14	50	20	49	44	151			14	095	1	1	
30	14	52	50	49	44	151			14	080	1	1	
31	14	55	0	49	44	151			33		1	1	
32	14	56	30	49	44	151			15	105	1	1	
33	14	58	20	49	44	151			31		1	1	
34	15	2	40	49	44	151			31		1	1	
35	15	5	20	49	44	151			33		1	1	
36	15	6	20	49	44	151			13	095	1	1	
37	15	8	10	49	44	151			14	095	1	1	
38	15	8	20	49	44	151			14	090	1	1	
39	15	9	30	49	44	151			33		1	1	
40	15	12	10	49	44	151			13	095	1	1	
41	15	12	50	49	44	151			14	090	1	1	
42	15	13	20	49	44	151			21		1	1	
43	15	14	30	49	44	151			33		1	1	40
44	15	15	0	49	44	151	9		11	110	1	1	

Table 4.4 - A

PAGE NO. 2

LINE	TIME HR	TIME MN	TIME SC	IDENTIFICATION DEP NUM	IDENTIFICATION OPR NUM	IDENTIFICATION JOB NUMBER	SPEC	INTER	WORKER A C	WORKER P RT	DAY NUM	SHIFT	LOT SIZ
45	7	51	30	49	44		8				3	1	
46	7	53	30	49	44	151			14	080	3	1	
47	7	54	30	49	44	151			14		3	1	
48	7	54	50	49	44	151			15		3	1	
49	7	55	20	49	44	151			12		3	1	
50	7	57	10	49	44	151			14	090	3	1	
51	7	57	40	49	44	151			13		3	1	
52	7	58	10	49	44	151			33		3	1	
53	7	59	0	49	44	151			14	080	3	1	
54	7	59	20	49	44	151			14	075	3	1	
55	8	3	30	49	44	151			14	090	3	1	
56	8	4	0	40	44	151			14		3	1	
57	8	4	30	49	44	151			14	095	3	1	
58	8	7	10	49	44	151			14		3	1	
59	8	8	20	49	44	151			34		3	1	
60	8	8	30	49	44	151			32		3	1	
61	8	8	40	49	44	151			14	090	3	1	
62	8	11	30	49	44	151			13		3	1	
63	8	11	50	49	44	151			14	095	3	1	
64	8	13	10	49	44	151			11	095	3	1	
65	8	13	30	49	44	151			14	090	3	1	
66	8	15	30	49	44	151			13		3	1	
67	8	17	30	49	44	151			14	095	3	1	
68	8	18	20	49	44	151			11	095	3	1	
69	8	19	20	49	44	151			14	090	3	1	
70	8	20	20	49	44	151			14		3	1	
71	8	20	40	49	44	151			33		3	1	
72	8	21	0	49	44	151			12	090	3	1	
73	8	21	10	49	44	151			14	095	3	1	
74	8	21	30	49	44	151			13	080	3	1	
75	8	21	40	49	44	151			33		3	1	
77	8	22	30	49	44	151			14	090	3	1	
78	8	24	30	49	44	151			13	090	3	1	
79	8	31	10	49	44	151			14	105	3	1	
80	8	33	0	49	44	151			13	090	3	1	
81	8	34	0	49	44	151			34		3	1	
82	8	35	10	49	44	151			13		3	1	
83	8	38	0	49	44	151			11	095	3	1	
84	8	38	10	49	44	151			13	095	3	1	
85	8	38	50	49	44	151			33		3	1	
86	8	39	50	49	44	151			15		3	1	
87	8	41	50	49	44	151			14	095	3	1	
88	8	47	30	49	44	151			14	095	3	1	

Table 4.4 - B

PAGE NO. 3

LINE	TIME HR	TIME MN	TIME SC	IDENTIFICATION DEP NUM	IDENTIFICATION OPR NUM	IDENTIFICATION JOB NUMBER	SPEC	INTER	WORKER A C	WORKER P RT	DAY NUM	SHIFT	LOT SIZ
89	8	48	0	49	44	151			14	095	3	1	
90	8	50	30	49	44	151			34		3	1	
91	8	55	30	49	44	151			14	095	3	1	
92	8	56	0	49	44	151			14	095	3	1	
93	8	56	30	49	44	151			14	090	3	1	
94	8	57	30	49	44	151			14		3	1	
95	8	58	40	49	44	151			34		3	1	
96	9	0	40	49	44	151			31		3	1	
97	9	2	29	49	44	151			31		3	1	
98	9	2	50	49	44	151			31		3	1	
99	9	5	10	49	44	151			34		3	1	
100	9	5	20	49	44	151			31		3	1	42
101	9	9	0	49	44		9				3	1	

>>>>>>>>>> END OF FILE

Table 4.4 - C

Each observation represents a computing card. This data was submitted to an IBM 360 computer, giving the following results :

JOB NUMBER	N	P	S	STD. TIME (MIN.)	STD. OUTPUT (PARTS/HOUR)
151	42	80.6%	±15%	.075	803
151	55	80.6%	±13%	.068	877
TOTAL	97	80.6%	±10%	.071	839

THERE WERE FOUR OPERATORS ATTENDING THE LINE.

Table 4.5

Where :

N = Number of readings.

P = Percentage of time the worker spent working.

S = Relative accuracy.

The pilot study proved to be satisfactory as far as the methodology was concerned. It took the analyst a short time to get used to the forms and also to relate activities to codes.

More work sampling studies were done in the packing line using the same activity codes already described.

The results are summarized in the following table:

JOB NUMBER	N	P	S	STD. OUTPUT (PARTS/HOUR)
01301020	244	93.2%	±3.5%	247
11017002	168	92.4%	±4.4%	179 **
11030100	55	87.3%	±10.3%	488
11033102	47	94.8%	±6.8%	644

THE LINE WAS ATTENDED BY THREE WORKERS.

Table 4.6

At this point in time, it became important to find out the effect of rating in the evaluation of the standard.

Table 4.7 shows a comparison between the standard calculated including and ignoring the rating factor.

JOB NUMBER	STD. CALCULATED WITHOUT RATING (LOCKS/HOUR)	STD. CALCULATED WITH RATING (LOCKS/HOUR)	RATIO
01301020	237	247	.960
11017002	172	179	.961
11030100	478	488	.980
11033102	652	644	1.012

Table 4.7

** An extra worker joined the crew half way through the study.

According to the results presented in Table 4.7, we can conclude that the rating factor is important in the setting of standards by work sampling.

All these work sampling studies were concurrently carried out with an ongoing stop-watch study programme.

4.8 RESULTS FROM STOP-WATCH STUDIES

Making use of the data collected by the personnel of the Industrial Engineering department of the local lock factory, the following results were obtained.

JOB NUMBER	STANDARD SET BY *WORK SAMPLING	ACTUAL *OUTPUT[1]	STANDARD SET BY *TIME STUDY
11017002	51	54	75
11030100	163	143	182

Table 4.8

The above figure shows that the standards set by means of work sampling were closer to the actual output reported by the foreman of the packing line.[2]

* This standard is measured in Locks/Hour/Worker for accounting purposes.

[1] Based on the average over a period of a month.

[2] This point will be discussed in the conclusions.

4.9 TIME REQUIRED TO SET THE STANDARD TIME

Table 4.9 shows the break down of an estimate of the time needed for an analyst to set standards following the two methods mentioned in this paper.

TIME STUDY[1]

	HOURS
Break down of the elements into components	.25
Taking the readings	2.50
Carrying out computations	1.00
TOTAL	3.75

WORK SAMPLING[2]

	HOURS
Establishing activity codes	.25
Taking the readings	5.00
Carrying out computations[3]	.25
TOTAL	5.50

Table 4.9

[1] This estimate is an appraisal from the personnel of the Industrial Engineering based on their time studies.

[2] Based on records kept during the preparation of this paper.

[3] Actually, required time to prepare and punch the data, since the computations themselves are carried out by an IBM computer.

4.10 SUMMARY OF THIS CHAPTER

From the studies presented in this chapter, the following conclusions were drawn :

1.- Work sampling is applicable to an assembly line operation.

2.- The rating factor seemed to be significant in fixing the standard time by means of work sampling.

3.- The time required to set standards was higher using work sampling than using time study.

CHAPTER V

WORK SAMPLING APPLIED TO A SHORT CYCLE OPERATION

In this chapter, a study carried out in the Latch Assembly Department is described. A brief explanation of how the readings are recorded during a work sampling study is also given.

A latch is an important constituent of a lock. In this factory, there are basically two types of latches. One of them is used in bedroom doors. The other one is found in house entrances or in some other places where more security is needed (see Appendix E).

5.1 WORK SAMPLING IN DEPARTMENT 41 LATCH-ASSEMBLY

First of all, the analyst must understand the mechanics of the assembly, its difficulties and peculiarities. At this stage the analyst would have to decide the pace or tempo that constitutes a normal performance. Equally important is the establishment of activity codes.

Figs. 5.1 to 5.3 illustrate some of the worker's activities and the working place. In this case, the parts for the assembly are supplied by indirect labour. It must be noted that the worker has all the pieces at hand and they are well organized; therefore a high percentage of production + production support is expected.

11.- Normal Production

Figure 5.1

21.- Testing latches

Figure 5.2

This is the working place, a self staking bench

Figure 5.3

Table 5.1 shows the activity codes for this study.

DEPARTMENT 41 - LATCH-ASSEMBLY

ACTIVITY CODES

Activity Code No.	Significance
	Production
11	Normal production. Assembly of parts.
	Production Support
21	Testing latches.
22	Changing boxes.
23	Repairing assembly or defective parts.
24	Unavoidable Delays: material is supplied to the bench, receiving instructions, recording production.
	Non-productive
31	Avoidable Delays: idle, talking .
32	Absent.
33	Clean-up

Table 5.1

In this case, the department number is 41, the operator number is the same as the bench number, and the job number is the assembly number at the time of observation.

Since the stations are fairly close to each other, the analyst was able to observe eight benches in the same day's study, taking 105 readings from each bench.

The following picture shows the general layout of this department.

Department 41 Latch Assembly

Figure 5.4

The analyst gathered his data using observation sheets described in the previous chapter (page 46), and shown in Appendix D . The following page is part of this study.

STATION NO. 1
PAGE NO.1

AUG,25,'77
COMMENTS

LINE	TIME HR:MN:S	IDENTIFICATION DEP NUM	IDENTIFICATION OPR NUM	IDENTIFICATION JOB NUMBER	SPEC	INTER	WORKER A C	WORKER P RT	DAY NUM	SHIFT	LOT SIZ
1	7:38:4	41	11	4			31		5	1	
2	7:41:2						11			1	
3	7:44:5						11	90		1	
4	7:49:5						11			1	
5	7:55:1						11			1	
6	8: 3:4						11			1	
7	8: 4:2						11			1	
8	8: 9:0						11			1	
9	8:12:0						11	105		1	
10	8:14:0						11			1	
11	8:22:2						11	105		1	
12	8:23:0						11			1	
13	8:23:4						11			1	
14	8:25:5						32			1	
15	8:31:3						11			1	
16	8:32:3						21			1	
17	8:33:0						21			1	
18	8:38:3						21			1	
19	8:40:2						11			1	
20	8:41:4						11			1	
21	8:42:2						11			1	

Table 5.2

Each line from the observation sheets is punched into an IBM computing card. The vertical line means that the information is to be repeated from the previous card. The listing of the first ten cards of the previous page is given in Table 5.3.

CARD	TIME			IDENTIFICATION			SPEC	INTER	WORKER			SHIFT	
	HR	MN	S	DEP NUM	OPR NUM	JOB NUMBER			ACT COD	RATE	DAY NUM		LOT SIZ
1	7	38	4	41	11	4			31		5	1	
2	7	41	2	41	11	4			11		5	1	
3	7	44	5	41	11	4			11	90	5	1	
4	7	49	5	41	11	4			11		5	1	
5	7	55	1	41	11	4			11		5	1	
6	8	3	4	41	11	4			11		5	1	
7	8	4	2	41	11	4			11		5	1	
8	8	9	0	41	11	4			11		5	1	
9	8	12	0	41	11	4			11	105	5	1	
10	8	14	0	41	11	4			11		5	1	

Table 5.3

Note that whenever the analyst rates the operator at normal performance (100%), the rating is left blank.

After the computing cards are checked and any mistakes by the analyst or the key-punch operator are corrected, the data is submitted to the computer.

The computer reads this data in the following manner:

CARD	TIME HR	TIME MN	TIME SC	IDENTIFICATION DP NM	IDENTIFICATION OPR NUM	IDENTIFICATION JOB NUMBER	SPEC	INTER	WORKER ACT COD	WORKER RATE	DAY NUM	SHIFT	LOT SIZ
1	7	38	40	41	11	4	–	–	31	0	5	1	–
2	7	41	20	41	11	4	–	–	11	100	5	1	–
3	7	44	50	41	11	4	–	–	11	90	5	1	–
4	7	49	50	41	11	4	–	–	11	100	5	1	–
5	7	55	10	41	11	4	–	–	11	100	5	1	–
6	8	3	40	41	11	4	–	–	11	100	5	1	–
7	8	4	20	41	11	4	–	–	11	100	5	1	–
8	8	9	0	41	11	4	–	–	11	100	5	1	–
9	8	12	0	41	11	4	–	–	11	105	5	1	–
10	8	14	0	41	–	4	–	–	11	100	5	1	–

Table 5.4

Note that in the case of non-productive activity (31), the computer assigns zero to the rating factor.

From this data the following results are obtained:

WORK MEASUREMENT SAMPLING SUMMARY +++++

COST CENTER	POS	JOB NUM	START DAY	PROD + PROD SUPPORT OBS	TOTAL OBS	AVG MAN HRS/PIECE
41	1	2	5	93	102	7.277
41	2	2	5	98	105	8.198
41	6	2	5	104	105	8.513
41	8	2	5	83	105	6.692
41	10	1	5	94	105	7.907
41	11	4	5	101	105	8.468
41	12	1	5	91	105	7.609
41	13	3	5	103	104	8.265

*** WMS SUMMARY COMPLETE

STANDARD TIME FROM WORK MEASUREMENT SAMPLING

JOB NUM	PERCENT P	RELATIVE ACCURACY	AVG MAN HRS.	TOTAL OUTPUT (PARTS)	STD TIME (MIN.)	STD OUTPUT PARTS/HR
2	90.35	± 3.2 %	30.680	3335	.552	109
1	93.10	± 3.7 %	22.698	4550	.299	200
3	99.10	± 2.0 %	8.265	1500	.331	181
4	96.19	± 3.8 %	8.468	875	.643	93

END OF THE JOB

EXECUTION TERMINATED

Table 5.5

+++++ These are the summarized results. For complete printouts see Appendix E.

Table 5.6 shows a comparison between the standard calculated without and with the rating factor.

JOB NUMBER	STD. CALCULATED WITHOUT RATING (LATCHES/HOUR)	STD. CALCULATED WITH RATING (LATCHES/HOUR)	RATIO
0 2 0	109	109	1.00
0 1 0	205	200	1.03
0 3 0	181	181	1.00
0 4 0	98	93	1.06

Table 5.6

Table 5.7 compares the standard set by work sampling with the actual output and the standards set by time study.

JOB NUMBER	STANDARD SET BY *WORK SAMPLING	ACTUAL *OUTPUT[1]	STANDARD SET BY *TIME STUDY
0 2 0	109	105	119
0 1 0	200	197	190
0 3 0	181	186	191
0 4 0	93	103	116

Table 5.7

---

* This standard is measured in Latches/Hour.

[1] Based on the report of January and February 1978.

In Table 5.7, it can be seen that the standards set by means of work sampling were closer to the actual output reported by the foreman of the latch assembly department.

5.2 TIME REQUIRED TO SET THE STANDARD TIME

The time needed by an analyst to set standards (computed in this chapter) by (i) work sampling and (ii) time study can be broken down as seen in the following table.

TIME STUDY	HOURS
Breaking down of the elements into components	.25
Taking the readings	4.50
Carrying out computations	2.50
TOTAL	7.25

WORK SAMPLING	HOURS
Establishing activity codes	.25
Taking the readings	7.50
Carrying out computations	.50
TOTAL	8.25

Table 5.8

5.3 SUMMARY OF THIS CHAPTER

From the study presented in this chapter, it can be concluded that:

1.- Work sampling is applicable to a short cycle repetitive operation such as the assembly of a latch, where the standard time varies from 0.3 to 0.6 minutes, depending on the type of latch (see Table 5.5).

2.- The rating factor seemed to have a small effect on the standard time obtained (see Table 5.6).

3.- The time required to set standards was 12% longer in the case of work sampling (see Table 5.8).

CHAPTER VI

CONCLUSIONS

1.- Instead of standard stop watch, work sampling can be applied to short cycle assembly operations without suffering any loss of accuracy.

2.- Work sampling appeared to be more expensive than time study in terms of actual man-hours required on tested applications studied. However, the accuracy achieved by means of work sampling was slightly higher than the accuracy obtained by time study since extra observations were taken.

A feed back method such as a simple programme for a portable programmable calculator could be used to compute the number of necessary readings for a given confidence level after a given number of readings. If this is done, it is likely that the economics in terms of man-hours would favour work sampling because the study could be terminated when the desired accuracy level was achieved.

3.- Work sampling must be considered to be a more acceptable method psychologically and could be performed by a less skilled, less expensive technician .

4.- The question of the importance of rating is controversial. It seems to be less important in work sampling and this may be related only to the grouping of elements necessitated in work sampling techniques.

5.- During the work sampling study, the analyst has more time to observe the operation for methods improvement.

BIBLIOGRAPHY

Whitmore D.A., WORK MEASUREMENT, The Institute of Practitioners in Work Study, Organisation and Methods, 1975.

International Labor Office, INTRODUCTION TO WORK STUDY, four impression 1974, Geneva.

Dun and Bradstreet, KEY BUSINESS RATIOS IN CANADA, 1973.

Merril Lynch Pierce Fenner & Smith Inc., HOW TO READ FINANCIAL REPORT, 1973.

Journals of Industrial Engineering. A.I.I.E.

Barnes R., MOTION AND TIME STUDY, Sixth Edition, John Wiley & Inc. 1968.

Mundel M., HANDBOOK OF INDUSTRIAL ENGINEERING AND MANAGEMENT, Second Edition, Prentice-hall, 1971.

Buffa E., MODERN PRODUCTION MANAGEMENT, Fourth Edition, John Wiley & Sons, 1973.

Bertrand L. Hansen, WORK SAMPLING FOR MODERN MANAGEMENT, Prentice-Hall Inc, 1960.

Schmid M., WORK MEASUREMENT SAMPLING, University of Dayton 1970.

Schmid M., APPLICATIONS MANUAL - WORK MEASUREMENT SAMPLING, University of Dayton, 1970.

Caruth D.L. GUIDELINES FOR ORGANIZING A WORK MEASUREMENT PROGRAM, 1971.

APPENDIX A

DETERMINING THE NUMBER OF CYCLES TO STUDY

TIME STUDY

The number of cycles which must be timed in order to attain a desired level of accuracy depends on the duration of the basic time of the cycle, and on the dispersion of the basic times obtained during the study.

Eq. 1 gives a measure of the variability of data about its average. The variability is represented by S, the standard deviation, which is expressed as follows:

$$S = \sqrt{\Sigma d^2/N} \qquad (1)$$

d = $X-\bar{X}$ computed from each reading of the element separetely before squaring and then summing.

X = Individual readings of an element.

$\bar{X}$ = Mean or average of all readings of an element.

Σ = Sum of like items.

N = Number of readings of an element.

This equation may be expressed as follows for machine computation (Friden, Monroe, Marchant, etc.):

$$S = \sqrt{\Sigma X^2/N - (\Sigma X/N)^2}$$
$$= 1/N\sqrt{N\Sigma X^2 - (\Sigma X)^2}$$

Assuming that this represents the varability of a huge group of similar readings or the parent population (a commonly tenable assumption), another measure, Sx, the standard error of the mean (or average), may be computed from Eq. 2, which indicates the probable variability of the averages of groups of N values of X about the mean value.

$$Sx = S/\sqrt{N} \qquad (2)$$

The property of this last measure is such that 95 per cent of the probable values of $\overline{X}$ (average of the element) will lie within $\pm 2Sx$ of the true average.

Hence, if 2Sx is equal or less than 5 per cent of X, we may say that the chances are at least 95 out of 100 that our average for the element to which the rating will be applied is whithin ± 5 per cent of the true average representing the performance we observed.

If the selected limiting condition is not met, we may work Eq. 2 backward, using the S we first obtained, setting 2Sx equal to 5 per cent of $\overline{X}$, and solving for N', which will indicate the number of the readings that will probabily be needed.

Indeed, it is this last property that makes this test feasible, easy and convenient, and economical to use, after certain mathematical manipulations of the formulas have been made.

Combining Eq. 1 and 2, we may state:

$$Sx = 1/N\sqrt{N\Sigma X^2 - (\Sigma X)^2}/\sqrt{N'}$$

Setting 5 per cent of X equal to 2Sx, we get:

$$0.05\overline{X} = \Sigma X/20N = (2)\left(1/N\sqrt{N\Sigma X^2 - (\Sigma X)^2}/\sqrt{N'}\right)$$

$$\Sigma X/20 = \left(2\sqrt{N\Sigma X^2 - (\Sigma X)^2}\right)/\sqrt{N'}$$

$$\text{and } N' = \left(40\sqrt{N\Sigma X^2 - (\Sigma X)^2}/\Sigma X\right)^2 \qquad (3)$$

Where N' is the required number of readings.

NUMBER OF OBSERVATIONS IN WORK SAMPLING

Work sampling or activity sampling is based on the theories of sampling and probability. The pilot study gives an estimate of the proportion (p) of time spent on a particular activity being studied. The limits of error are set two standard deviations (or, more correctly, two standard errors) from this estimate in order to ensure that the observer may be 95 per cent confident that the estimated error is correct.

The standard-error formula for a binomial distribution is:

$$\sqrt{p(1-p)/N}$$

Where N is the number of observations which must be made to ensure a certain required accuracy. The limits are set at two errors, therefore:

$$\text{Limits of error}(L) = 2\sqrt{p(1-p)/N}$$

Rearranging this formula produces one for estimating the number of observations required to attain a required error:

$$N = 4p(1-p)/L^2$$

$$\text{setting } L = 0.05p$$

$$N = 1600(1-p)/p$$

APPENDIX B

1.- Improved observation sheet for Work Sampling study.

2.- Programme for a Hewlett Packard calculator to generate random times during the available time for production.

3.- Form for recording the random times.

WORK SAMPLING STUDY

Sheet No.__________

Date__________

DEPARTMENT 49 - PACKING LINE

ACTIVITY		TOTAL	PERCENTAGE
1. Open box			
2. Insert strike			
3. Assemble trims and place in box			
4. Insert latch, screw packs			
5. Fill shipping case, close box			
6. Prepare material, remove empty boxes			
7. Walking			
8. Waiting for parts			
9. Pick up parts from the floor			
10. Out of area			
11. Conversing			

TOTAL WORKING ________%

OUTPUT = ________

TOTAL IDLE ________%

P.F.A. = ________%

HP-25 Program Form

Title RANDOM TIME FOR A WORK SAMPLING Page 1 of 1

Programmer H. VILLALOBOS

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS				OUTPUT DATA/UNITS
1	KEY IN PROGRAM						
2	STORE SEED	U_0	STO	0	F	PGRM	
3	STORE THE TIME FOR:						
3.1	START FIRST COFFEE BREAK	START 1	STO	1			
3.2	END FIRST COFFEE BREAK	END 1	STO	2			
3.3	START LUNCH	START 2	STO	3			
3.4	END LUNCH	END 2	STO	4			
3.5	START SECOND COFFEE BREAK	START 3	STO	5			
3.6	END SECOND COFFEE BREAK	END 3	STO	6			
3.7	CLEAN-UP	START 4	STO	7			
4	GENERATE RANDOM		R/S				t
	TIMES						
	THE CALCULATOR WILL GENERATE						
	AN INFINITE NUMBER OF						
	RANDOM TIMES.						
	THE ANALYST WILL GENERATE AS						
	MANY AS HE WILL NEED.						
	AT THE END OF THE RUN,						
	U_i IS RECORDED AND USED		F	FIX	9		
	FOR THE NEXT RUN.		RCL	0			U_i

HP-25 Program Form

Title RANDOM TIMES FOR OBSERVATIONS DURING TIME AVAILABLE FOR PRODUCTION   Page 1 of 1

Switch to PRGM mode, press [f] [PRGM], then key in the program.

DISPLAY LINE	DISPLAY CODE	KEY ENTRY	X	Y	Z	T	COMMENTS
00							
01	1573	g π	π				
02	2400	RCL 0	U_{i-1}	π			
03	51	+	$U_{i-1}+\pi$				
04	05	5	5	$U_{i-1}+\pi$			
05	1403	f x^y	$(U_{i-1}+\pi)^5$				
06	1501	g FRAC	U_i				
07	2300	STO 0	U_i				
08	08	8	8	U_i			
09	73	.	8.	U_i			
10	05	5	8.5	U_i			
11	61	x	$8.5U_i$				
12	07	7	7	$8.5U_i$			
13	73	.	7.	$8.5U_i$			
14	05	5	7.5	$8.5U_i$			
15	51	+	$7.5+8.5U_i$	= t			A RANDOM NUMBER BETWEEN 7.5 & 16.0
16	2401	RCL 1	START 1	t			
17	21	x⇄y	t	START 1			
18	1441	f x<y	t	START 1			
19	1344	GTO 44		START 1			TEST FOR THE FIRST DELAY.
20	2402	RCL 2	END 1	t			
21	1451	f x≥y	END 1	t			
22	1301	GTO 01	END 1	t			
23	21	x⇄y	t	END 1			
24	2403	RCL 3	START 2	t			
25	21	x⇄y	t	START 2			
26	1441	f x<y	t	START 2			
27	1344	GTO 44	t	START 2			TEST FOR THE SECOND DELAY.
28	2404	RCL 4	END 2	t			
29	1451	f x≥y	END 2	t			
30	1301	GTO 01	END 2	t			
31	21	x⇄y	t	END 2			
32	2405	RCL 5	START 3	t			
33	21	x⇄y	t	START 3			
34	1441	f x<y	t	START 3			
35	1344	GTO 44	t	START 3			TEST FOR THE THIRD DELAY.
36	2406	RCL 6	END 3	t			
37	1451	f x≥y	END 3	t			
38	1301	GTO 01	END 3	t			
39	21	x⇄y	t	END 3			
40	2407	RCL 7	START 4	t			
41	1441	f x<y	START 4	t			TEST FOR THE FOURTH DELAY.
42	1301	GTO 01	START 4	t			
43	21	x⇄y	t	START 4			
44	1400	f H.MS	t				
45	1478	f R/S	t				
46	1478	f R/S	t				THE TIME IS DISPLAYED FOUR TIMES.
47	1478	f R/S	t				
48	1478	f R/S	t				
49	1301	GTO 01	t				

REGISTERS	
R_0	U_0
R_1	START 1
R_2	END 1
R_3	START 2
R_4	END 2
R_5	START 3
R_6	END 3
R_7	START 4

U_i = FRACTIONAL PART OF $[(\pi+U_{i-1})^5]$

WHERE $0 \le U \le 1$

$t_i = 7.5 + 8.5U_i$

WORK SAMPLING STUDY

RANDOM TIMES FOR OBSERVATIONS

Minutes	7	8	9	10	11	12	13	14	15
10						Lunch Time			
20									
30									
40								Coffee Break	
50			Coffee Break						
60					Lunch Time				Clean-up

PSEUDO RANDOM TIMES
UNIFORMLY DISTRIBUTED

$o < U_i < 1$

U_i = Fractional part of $[(\pi + U_{i-1})^5]$

U_{i-1} = __________

U_o = __________

Date = __________

APPENDIX C

Programme for a Hewlett Packard calculator for finding the number of cycles required in a Time Study to achieve 95 % confidence within ± 5 % of error.

HP-25 Program Form

Title BEQUIRED READINGS FOR 95% CONFIDENCE WITHIN ±5% ERROR Page 1 of 1

Programmer H. VILLALOBOS / MARCH 2, 1978

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS				OUTPUT DATA/UNITS
1	KEY IN PROGRAM						
2	INITIALIZE		F	PRGM			
3	ENTER CYCLE TIME	x_1	NO —	KEYS			
4	ONLY IF THE						
	OPERATOR IS TO BE						
	RATED, FOLLOW THE						
	NEXT 2 STEPS;						
	OTHERWISE SKIP THEM.						
5	PRESS ENTER		E↑				
6	ENTER THE RATING	R	NO —	KEYS			
7	RUN FOR FIRST CYCLE		R/S				N
8	REPEAT STEPS						
	3 TO 7, 10 TIMES						
9	FIRST ESTIMATE OF						N', N
	N' FLASHES TWICE						
10	KEY FEEDING DATA						N', N
	UNTIL N APPROACHES						
	N'						
11	THE PROGRAM						X_{MEAN}
	STOPS WHEN						
	N > N'						
12	FOR A NEW CYCLE		R/S				
	PRESS R/S BEFORE						
	ENTERING THE						
	FIRST READING						
	NOTE TO THE USER:						
a)	IF RATING IS NOT SPECIFIED						
	THE PROGRAM ASSUMES 100						
b)	THE PROGRAM TAKES ANY						
	KINDS OF UNITS OF TIME.						

HP-25 Program Form

Title: REQUIRED READING FOR 95% CONFIDENCE WITH ±5% ERROR   Page 1 of 1

Switch to PRGM mode, press [f] [PRGM], then key in the program: MARCH 2, 1978

LINE	CODE	KEY ENTRY	X	Y	Z	T	COMMENTS
00			R	x			
01	21	x⇄y	x	R			
02	1571	gx=0	x	R			
03	1309	GTO 09					LOOP FOR THE
04	61	x	Rx				
05	33	EEx	1	Rx			FIRST TEN CYCLES.
06	02	2	100	Rx			
07	71	÷	Rx				
08	1310	GTO 10	Rx				
09	22	R↓	Rx				
10	25	Σ+	N				
11	31	E↑	N				
12	01	1	1	N			
13	00	0	10	N			
14	21	x⇄y	N	10			
15	1441	Fx<y	N	10			
16	1347	GTO 47	N	10			
17	2406	RCL 6	Σx^2	N	10		N' IS COMPUTED
18	61	x	$N\Sigma x^2$	10			
19	2407	RCL 7	Σx	$N\Sigma x^2$			
20	1502	gx^2	$(\Sigma x)^2$	$N\Sigma x^2$	10		
21	41	−	$N\Sigma x^2-(\Sigma x)^2$	10			$A^2 = N\Sigma x^2 - (\Sigma x)^2$
22	1402	F√x	A	10			
23	04	4	4	A	10		
24	61	x	4A	10			
25	61	x	40A				
26	2407	RCL 7	Σx	40A			
27	71	÷	$40A/\Sigma x$				
28	1502	gx^2	N'				
29	141100	FIX 0	N'				
30	1474	F R/S	N'				
31	1474	F R/S	N'				
32	141102	FIX 2	N'				
33	2403	RCL 3	N	N'			
34	1441	Fx<y	N	N'			
35	1347	GTO 47	N	N'			
36	1421	F$\bar{x}$	X_{MEAN}				MEAN READING
37	74	R/S	x				READ $\bar{x}$
38	1433	F REG	$\bar{x}$				
39	1348	GTO 48		→	→	→	EXIT TO A NEW CYCLE.
40							
41							
42							
43							
44							
45							
46							
47	1471	F R/S					CLEAR THE
48	1434	F STK					STACKS.
49	1300	GTO 00					

REGISTERS	
R_0	
R_1	
R_2	
R_3	N
R_4	
R_5	
R_6	$\Sigma(Rx)^2$
R_7	ΣRx

$$N' = \left(\frac{40\sqrt{N\Sigma x^2 - (\Sigma x)^2}}{\Sigma x}\right)^2$$

APPENDIX D

1.- IBM programme for generating random times under uniform distribution during time available for production for Work Sampling study.

2.- An example covering two positions or stations with forty two observations each.

```
$SIGNON WMSA FORM=8X11 PAGES=50 PRIO=LOW 'U B C UBC'
THIS IS NOT A PASSWORD !!!!!
$RUN *FTN SCARDS=*SOURCE* PAR=NOSOURCE
C          **************************************************
C
C          THIS PROGRAM FINDS RANDOM TIMES UNDER UNIFORM
C          DISTRIBUTION FOR A WORK SAMPLING STUDY.
C
C          IT IS ARBITRARILY SET FOR WEISER, WHEN THE
C          SHIFT IS CONSIDERED NUMBER ONE, STARTING AT
C          7:30, AND FINISHING AT 16:00.
C          THERE ARE FOUR SCHEDULED DELAYS; AT 9:40,
C          11:50, 14:30 AND 15:55. THE LENGTH OF
C          THE DELAYS IS:  0:15, 0:30, 0:12 AND 0:05.
C
C     >>>>> NOTE:
C           9:20= 9.333      9.35= 9.583
C           9:40= 9.666      9:55= 9.916
C          11:45=11.750     12:15=12.250
C          11:50=11.833     12:20=12.333
C          12:30=12.500     13:00=13.000
C          14:30=14.500     14:42=14.700
C     >>>>>15:55=15.916     16:00=16.000
C
C          THIS PROGRAM USES TWO SUBROUTINES FROM THE
C          LIBRARY, ONE IS CALLED 'RAND', WHICH GENERATES
C          RANDOM NUMBERS, AND THE OTHER ONE IS CALLED
C          'SSORT', WHICH SORTS THE TIMES IN ASCENDING ORDER.
C
C          **************************************************
C          >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
C
C          >>>>>>>>NOTE TO THE USER OF THIS PROGRAM :
C
C          THE NUMBER 3 IS ATTACHED TO A FILE. IT HAS TO BE
C          DECLARED IN THE RUNNING COMMAND
C          THE ONLY CARD THIS PROGRAM REQUIRES IS, USING
C          COLUMNS 1 AND 4 THE NUMBER OF PAGES AND THE NUMBER
C          OF JOBS TO BE STUDIED.
C          >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
C
         DIMENSION TIME(2187),IHR(2187),MIN(2187),ISEC(2187)
C
C     *    READ THE SEED FROM FILE 'SEED' AND SAVE IT.
C
         READ(3,1) SEED
     1   FORMAT(F8.7)
         SAVSED=SEED
C
C     *    INITIALIZE COUNTER
C
         J=0
C
C     *    LOOKS FOR A VALUE FOR NUMBER OF
C     *    OBSERVATIONS REQUIRED. IF IT DOESN'T
C     *    FIND IT IN CARDS, IT ASSIGNS 1 TO
C     *    NUMBER OF JOBS AND 1 TO THE NUMBER
C     *    OF PAGES (27 OBSERVATIONS).
C
         READ(5,2,END=3,ERR=3) NP,NJOB
```

```
  2   FORMAT(I2,1X,I2)
      GO TO 4
  3   WRITE(6,25)
 25   FORMAT(1X,20X,19HERROR IN DATA****** )
      NP=1
      NJOB=1
C
C    *     THE TOTAL NUMBER OF OBSERVATIONS IS FOUND
C
  4   IF(NJOB.LE.1) NJOB=1
      IF(NP.LE.1) NP=1
      N=NP*21*NJOB
C
C    *     THE ELEMENTS OF THE ARRAY TIME ARE GENERATED
C
  5     CONTINUE
        SEED=RAND(SEED)
        T=7.5+8.5*SEED
C
C      *****************************************************
C
C    *     CHECK IF TIME IS WHITHIN PRODUCTIVE PERIOD
C
C     *****************************************************
C      >>>>>>>>>> FIRST COFFEE BREAK >>>>>>>>> 15 MIN=.25 HR.
C
              IF((T.GE.9.3333).AND.(T.LE.9.5833)) GO TO 5
C
C      >>>>>>>>>> LUNCH TIME........... 30 MIN=.50 HR.
C
              IF((T.GE.11.833).AND.(T.LE.12.333)) GO TO 5
C
C      >>>>>>>>>> SECOND COFFEE BREAK >>>>>>>>> 12 MIN=.20 HR.
C
              IF((T.GE.14.500).AND.(T.LE.14.700)) GO TO 5
C
C     >>>>>>>>>>> CLEAN UP TIME >>>>>>>> 5 MIN=.08 HR.
C
              IF (T.GT.15.916)                GO TO 5
C
C    *      OBSERVATION WITHIN PRODUCTIVE TIME
C
        J=J+1
        TIME(J)=T
        IF(J.LT.N) GO TO 5
C
C
C    *     THE ELEMENTS ARE SORTED USING A SUBROUTINE FROM THE LIBRARY
C
      CALL SSORT(TIME,N,3)
C
C
C    *     TIME IS CONVERTED TO 'HR,MIN,SEC'
C
         DO 8 I=1,J
         IHR(I)=IFIX(TIME(I))
         XMIN=60.0*(TIME(I)-FLOAT(IHR(I)))
         MIN(I)=IFIX(XMIN)
         ISEC(I)=IFIX(6.0*(XMIN-FLOAT(MIN(I)))+0.005)
  8      CONTINUE
```

```
C
C     *     NOTE: ISEC(I) REPRESENTS 10 SECONDS
C
C         <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
C         THIS PART OF  THE PROGRAM PRINTS THE FORMS FOR
C         WORK SAMPLING STUDY.
C
C         IT ALSO PRINTS THE RANDOM TIMES FOR THE OBSERVATIONS.
C
C         NOTE : THIS PARTICULAR FORMAT HAS BEEN DEVELOPED
C         FOR WEISER LOCK CO. IN CANADA
C         <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
C
C     *
C
   10  FORMAT('1',
      -55H _______________________________________________________,
      -1X,7HSTATION )
   20  FORMAT(1X,
      -55H| L | TIME    |  IDENTIFICATION  |S|I| WORKER |   |S|   |
      - 2X,3HNO.,I2)
   30  FORMAT('+',
      -55H       __________________________      ________         )
           - 2X,3HNO.,I2)
   40  FORMAT(1X,
      -55H| I |    |   |  |DEP|OPR|   JOB    |P|N|    |    |DAY|H|LOT|,
      - 1X,8HPAGE NO.,I1)
   50  FORMAT(1X,
      -55H| N |HR:MN:S|NUM|NUM|  NUMBER   |E|T|A C|P RT|NUM|I|SIZ|)
   60  FORMAT(1X,
      -55H| E |  |  |  |    |   |          |C|E|   |    |F|   |,
      - 1X,9HDATE____ )
   65  FORMAT(1X,
      -55H|   |  |  |  |    |   |          | |R|   |    |T|   |,
      - 1X,8HCOMMENTS )
   70  FORMAT('+',
      -55H _______________________________________________________)
  100  FORMAT(1X,1H|,I3,1H|,I2,1H:,I2,1H:,I1,
      -               43H|    |   |          | | |   |    |1|   |)
  110  FORMAT(1X,
      -55H|   |                               | | |               |)
C
C     *     INITIALIZE COUNTERS FOR THE LOOP
C
       NFIRST=0
       LAST=N-NJOB
C
C     *     PRINT THE FIRST HEADING OR RETURN AFTER PRINTING 27 LINES
C
       DO 250 I=1,NJOB
            NSTOP=0
            LINE=0
            NPAGE=1
            NFIRST=NFIRST+1
            LAST=LAST+1
C
C              >>>>>PRINT THE HEADING
C
            WRITE(6,10)
            WRITE(6,20) I
```

```
                WRITE(6,30)
                WRITE(6,40) NPAGE
                WRITE(6,50)
                WRITE(6,60)
                WRITE(6,65)
                WRITE(6,70)
C
C    *        >>THE OBSERVATION SHEET IS PRINTED
C
                DO 200 K=NFIRST,LAST,NJOB
                   LINE=LINE+1
                   NSTOP=NSTOP+1
                   WRITE(6,110)
                   WRITE(6,100)NSTOP,IHR(K),MIN(K),ISEC(K)
                   WRITE(6,70)
C
C    *              ************ TEST FOR NEW PAGE
C
                   IF((LINE.GE.21).AND.(K.LT.LAST)) GO TO 170
C
                   GO TO 200
    170              LINE=0
                     NPAGE=NPAGE+1
                     WRITE(6,10)
                     WRITE(6,20) I
                     WRITE(6,30)
                     WRITE(6,40) NPAGE
                     WRITE(6,50)
                     WRITE(6,60)
                     WRITE(6,65)
                     WRITE(6,70)
    200            CONTINUE
C
C    *
C
C
    250         CONTINUE
C
    300   WRITE(6,350) SAVSED,NJOB,NP,SEED
    350   FORMAT('0',/
         1 20X,35HTHE ORIGINAL SEED FOR THIS RUN IS :,1X,F8.7,/
         2 21X,7HFOR :  ,I2,14H STATIONS WITH,1X,I2,12H PAGES EACH.,///
         3 29X,          26HTHE SEED FOR NEXT RUN IS :,1X,F8.7,///
         4 58X,14HEND OF THE RUN ////)
C
C    *    THE 'SEED' IS SAVED FOR THE NEXT RUN
C
          BACKSPACE 3
          WRITE(3,1) SEED
          STOP
          END
$Run -load 3=seed 7=-temp T=3

2/02
$Signoff
```

STATION NO. 1
PAGE NO. 1

DATE____
COMMENTS

LINE	TIME HR:MN:S	IDENTIFICATION DEP NUM	OPR NUM	JOB NUMBER	SPEC	INTER	WORKER A C	P RT	DAY NUM	SHIFT	LOT SIZ
1	7:32:0									1	
2	7:35:4									1	
3	7:46:2									1	
4	7:55:1									1	
5	7:59:1									1	
6	8:27:5									1	
7	8:48:3									1	
8	8:53:2									1	
9	8:58:1									1	
10	9: 4:0									1	
11	9:58:2									1	
12	10: 6:4									1	
13	10:14:3									1	
14	10:32:3									1	
15	10:44:4									1	
16	10:46:1									1	
17	10:47:4									1	
18	11: 6:2									1	
19	11:22:1									1	
20	11:29:3									1	
21	11:41:5									1	

STATION NO. 1
PAGE NO. 2

DATE____
COMMENTS

LINE	TIME	IDENTIFICATION			SPEC	INTER	WORKER		DAY NUM	SHIFT	LOT SIZ
	HR:MN:S	DEP NUM	OPR NUM	JOB NUMBER			A C	P RT			
22	11:45:4									1	
23	12:21:1									1	
24	12:31:2									1	
25	12:35:3									1	
26	12:38:5									1	
27	12:57:5									1	
28	12:59:5									1	
29	13: 3:4									1	
30	13:20:5									1	
31	13:36:3									1	
32	13:44:4									1	
33	13:56:2									1	
34	14: 5:0									1	
35	14:14:4									1	
36	14:19:3									1	
37	14:48:4									1	
38	14:51:5									1	
39	15: 6:0									1	
40	15:18:0									1	
41	15:28:1									1	
42	15:32:3									1	

STATION NO. 2
PAGE NO. 1

DATE____
COMMENTS

LINE	TIME HR:MN:S	IDENTIFICATION DEP NUM	OPR NUM	JOB NUMBER	SPEC	INTER	WORKER A C	P RT	DAY NUM	SHIFT	LOT SIZ
1	7:35:1									1	
2	7:37:4									1	
3	7:46:4									1	
4	7:58:3									1	
5	8:17:2									1	
6	8:34:4									1	
7	8:50:0									1	
8	8:55:5									1	
9	8:58:3									1	
10	9:13:1									1	
11	9:59:0									1	
12	10:13:5									1	
13	10:24:2									1	
14	10:40:1									1	
15	10:45:1									1	
16	10:47:1									1	
17	10:51:1									1	
18	11:15:3									1	
19	11:28:5									1	
20	11:31:0									1	
21	11:43:2									1	

STATION NO. 2
PAGE NO.2

DATE____
COMMENTS

LINE	TIME HR:MN:S	IDENTIFICATION DEP NUM	OPR NUM	JOB NUMBER	SPEC	INTER	WORKER A C	P RT	DAY NUM	SHIFT	LOT SIZ
22	11:47:4									1	
23	12:29:3									1	
24	12:32:1									1	
25	12:36:4									1	
26	12:46:1									1	
27	12:59:1									1	
28	13: 0:3									1	
29	13: 3:5									1	
30	13:29:1									1	
31	13:39:4									1	
32	13:48:3									1	
33	13:57:0									1	
34	14: 7:5									1	
35	14:16:5									1	
36	14:20:3									1	
37	14:50:3									1	
38	14:57:4									1	
39	15:17:3									1	
40	15:23:2									1	
41	15:31:5									1	
42	15:42:3									1	

THE ORIGINAL SEED FOR THIS RUN IS : .576090
FOR : 2 STATIONS WITH 2 PAGES EACH.

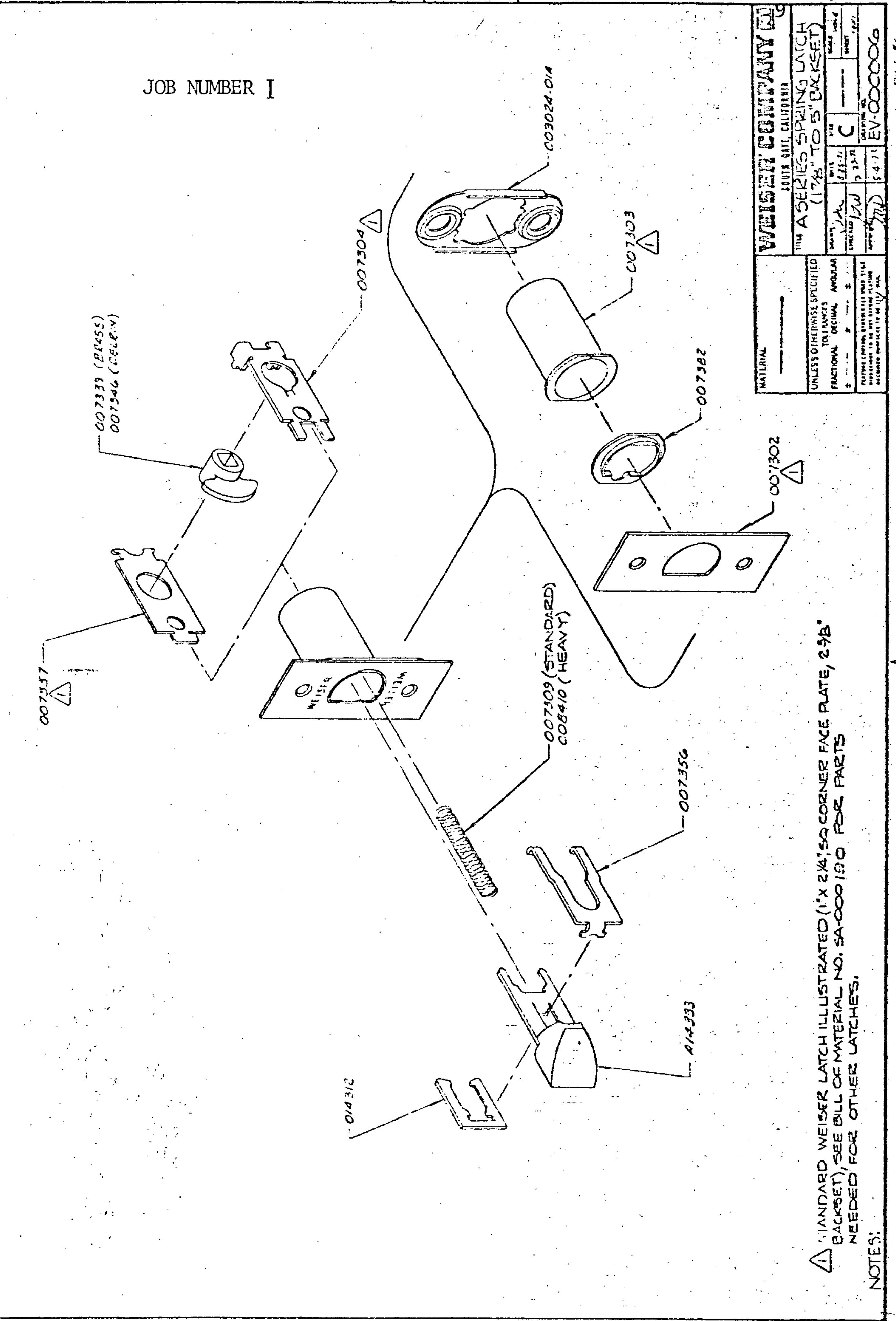
THE SEED FOR NEXT RUN IS : .011186

APPENDIX E

1.- Explosive view of the latches described in Chapter fcur.

2.- An example of the printouts obtained from the computer.

JOB NUMBER I

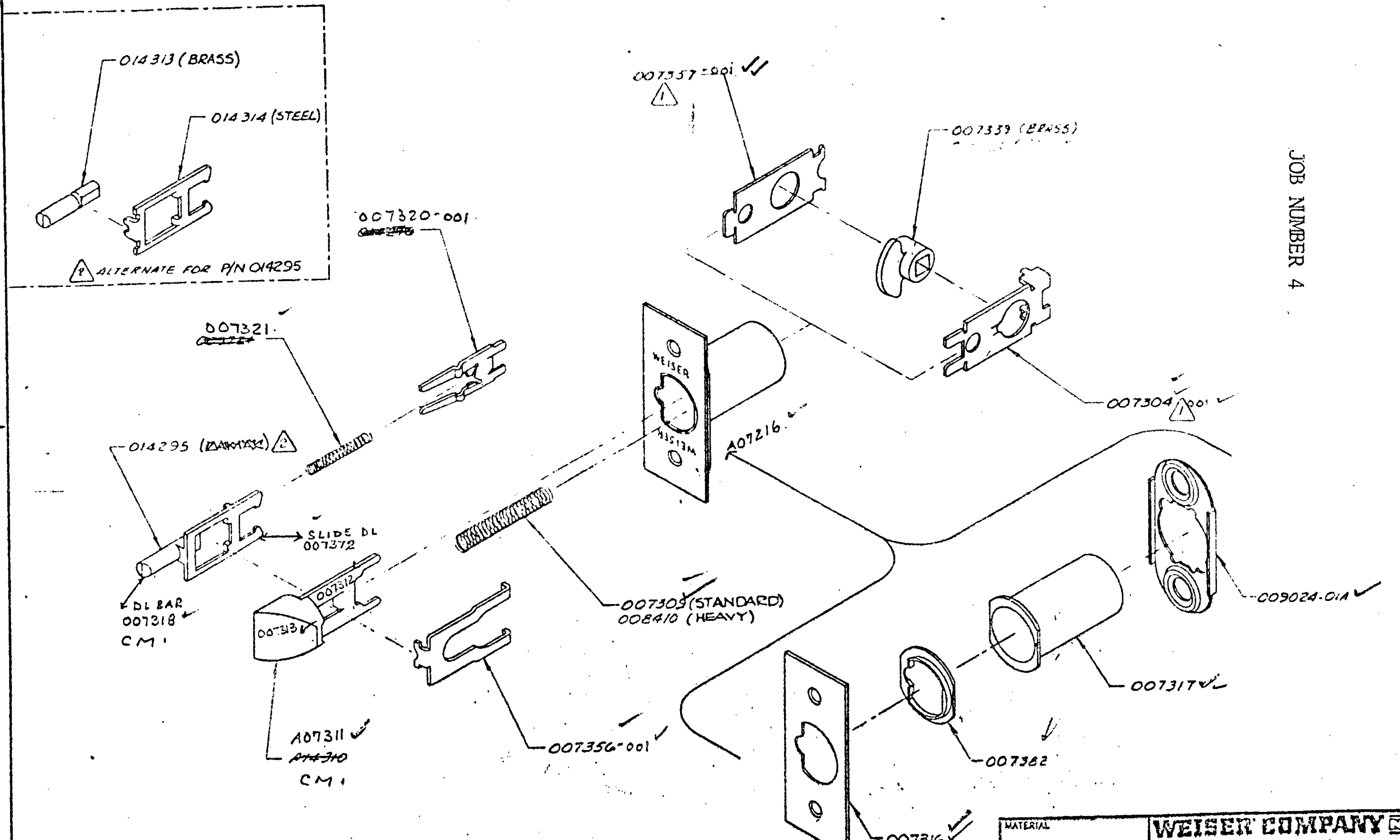


WEISER COMPANY
SOUTH GATE, CALIFORNIA
A SERIES SPRING LATCH (1 7/8" TO 5" BACKSET)
MATERIAL
UNLESS OTHERWISE SPECIFIED TOLERANCES
FRACTIONAL DECIMAL ANGULAR
C
EV-000006
003024-014
007303
007382
007302
007304
007339 (BRASS)
007346 (DELRIN)
007357
007309 (STANDARD)
008410 (HEAVY)
007356
014333
014312
NOTES:
STANDARD WEISER LATCH ILLUSTRATED (1"x 2 1/4" SQ CORNER FACE PLATE, 2 3/8" BACKSET) SEE BILL OF MATERIAL NO. SA-000190 FOR PARTS NEEDED FOR OTHER LATCHES.

A54230-ODW (SPECIAL· BRASS FACEPLATE (BRASS HUB))
2 3/4" BACK SET

OCT 29 1973

JOB NUMBER 4



NOTES:

2. PART NO. 014295 IS A ONE-PIECE ZAMAK DL BAR AND SLIDE. ALTERNATE CONSTRUCTION IS A TWO-PIECE DL BAR (BRASS) AND DL SLIDE (STEEL).

1. STANDARD WEISER LATCH ILLUSTRATED (1" X 2 1/4" SQ CORNER FACE PLATE, 2 3/8 BACKSET, ZAMAK BOLT AND DL BAR), SEE BILL OF MATERIAL NO. SA-000008 FOR PARTS NEEDED FOR OTHER LATCHES.

MATERIAL

UNLESS OTHERWISE SPECIFIED TOLERANCES
FRACTIONAL ± — DECIMAL ± — ANGULAR ± —

WEISER COMPANY
SOUTH GATE, CALIFORNIA

TITLE A SERIES D.L. LATCH (2 3/8" TO 5" BACKSET)

SIZE C

DRAWING NO. EV-000005

DWG #5

```
UU        UU  BBBBBBBBBBB    CCCCCCCCCC
UU        UU  BBBBBBBBBBBB  CCCCCCCCCCCC
UU        UU  BB        BB  CC        CC
UU        UU  BB        BB  CC
UU        UU  BB       BB   CC
UU        UU  BBBBBBBBBB    CC
UU        UU  BBBBBBBBBB    CC
UU        UU  BB       BB   CC
UU        UU  BB        BB  CC
UU        UU  BB        BB  CC        CC
UUUUUUUUUUUU  BBBBBBBBBBBB  CCCCCCCCCCCC
 UUUUUUUUUU   BBBBBBBBBBB    CCCCCCCCCC


              WW        WW  MM        MM   SSSSSSSSSS    AAAAAAAAAA
              WW        WW  MMM      MMM  SSSSSSSSSSSS  AAAAAAAAAAAA
              WW        WW  MMMM    MMMM  SS        SS  AA        AA
              WW        WW  MM MM  MM MM  SS            AA        AA
              WW        WW  MM  MMMM  MM  SSS           AA        AA
              WW        WW  MM   MM   MM   SSSSSSSSS    AAAAAAAAAAAA
              WW   WW   WW  MM        MM    SSSSSSSSS   AAAAAAAAAAAA
              WW  WWWW  WW  MM        MM         SSS    AA        AA
              WW WW  WW WW  MM        MM          SS    AA        AA
              WWWW    WWWW  MM        MM  SS      SS    AA        AA
              WWW      WWW  MM        MM  SSSSSSSSSSSS  AA        AA
              WW        WW  MM        MM   SSSSSSSSSS   AA        AA
```

```
$RUN WMS.OB 5=PARAM(1,6)+DATA-41+PARAM(7) 6=*SINK*
 7=*DUMMY* 8=-FILE8 9=-FILE9 10=-FILE10 11=-FILE11
```

EXECUTION BEGINS

WMS- EDIT INPUT PARAMETERS

ACTIVITY CODES	-	11	21	22	23	24	31	32	33

SHIFT NUMBERS	-	1	2	3	4
SHIFT START TIMES	-	750	9999	9999	9999
SHIFT END TIMES	-	1600	9999	9999	9999

		DELAY 1	DELAY 2	DELAY 3	DELAY 4	DELAY 5
START	1	933	1175	1450	1591	9999
	0	9999	9999	9999	9999	9999
	0	9999	9999	9999	9999	9999
	0	9999	9999	9999	9999	9999
LENGTH						
	1	25	50	20	8	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
ACCUM. DELAYS						
	1	25	75	95	103	103
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

GAMA = 0.80

READ DATA CARDS COMPLETE
TOTAL DATA CARDS - 840
SORT FOR PART 1 COMPLETE
*** WMS PART 1 COMPLETE
SORT FOR PART 2 COMPLETE

WMS PART 2 - END OF JOB

WORK SAMPLING SUMMARY PAGE 1

	IDENTIFICATION		ACTIVITY CODES								
	CC	POS	11	21	22	23	24	31	32	33	TOT
NO. OBSERVATIONS	41	1	82	11	1	0	2	1	8	0	105
ACT. (NOT RATED)	41	1	78.1	10.5	1.0	0.0	1.9	1.0	7.6	0.0	
ACT. (RATED)	41	1	75.7	10.5	1.0	0.0	1.9	0.0	0.0	0.0	89.0
NO. OBSERVATIONS	41	2	80	13	0	1	4	1	6	0	105
ACT. (NOT RATED)	41	2	76.2	12.4	0.0	1.0	3.8	1.0	5.7	0.0	
ACT. (RATED)	41	2	78.3	12.4	0.0	1.0	3.8	0.0	0.0	0.0	95.4
NO. OBSERVATIONS	41	6	90	12	0	1	1	0	1	0	105
ACT. (NOT RATED)	41	6	85.7	11.4	0.0	1.0	1.0	0.0	1.0	0.0	
ACT. (RATED)	41	6	85.8	11.4	0.0	1.0	1.0	0.0	0.0	0.0	99.1
NO. OBSERVATIONS	41	8	64	17	0	1	1	8	14	0	105
ACT. (NOT RATED)	41	8	61.0	16.2	0.0	1.0	1.0	7.6	13.3	0.0	
ACT. (RATED)	41	8	60.9	15.1	0.0	1.0	1.0	0.0	0.0	0.0	77.9
NO. OBSERVATIONS	41	10	89	0	2	3	0	5	5	1	105
ACT. (NOT RATED)	41	10	84.8	0.0	1.9	2.9	0.0	4.8	4.8	1.0	
ACT. (RATED)	41	10	87.3	0.0	1.9	2.9	0.0	0.0	0.0	0.0	92.0
NO. OBSERVATIONS	41	11	97	2	1	0	1	1	3	0	105
ACT. (NOT RATED)	41	11	92.4	1.9	1.0	0.0	1.0	1.0	2.9	0.0	
ACT. (RATED)	41	11	94.9	1.9	1.0	0.0	1.0	0.0	0.0	0.0	98.7
NO. OBSERVATIONS	41	12	89	0	1	1	0	5	8	1	105
ACT. (NOT RATED)	41	12	84.8	0.0	1.0	1.0	0.0	4.8	7.6	1.0	
ACT. (RATED)	41	12	86.7	0.0	1.0	1.0	0.0	0.0	0.0	0.0	88.6
NO. OBSERVATIONS	41	13	101	0	0	1	1	1	0	0	104
ACT. (NOT RATED)	41	13	97.1	0.0	0.0	1.0	1.0	1.0	0.0	0.0	
ACT. (RATED)	41	13	97.2	0.0	0.0	1.0	1.0	0.0	0.0	0.0	99.1
NO. OBSERVATIONS	TOTAL		692	55	5	8	10	22	45	2	839
ACT. (NOT RATED)	TOTAL		82.5	6.6	0.6	1.0	1.2	2.6	5.4	0.2	
ACT. (RATED)	TOTAL		83.3	6.4	0.6	1.0	1.2	0.0	0.0	0.0	92.5

WS OUTPUT FILE COMPLETE
END OF JOB RUN

WORK MEASUREMENT SAMPLING SUMMARY PAGE NO 1

COST CENTER	POS	JOB NUMBER	START DAY	PROD + PROD SUPPORT OBS	TOTAL OBS	AVG MAN HRS / PIECE
41	1	0 2 0	5	93	102	7.277
41	2	0 2 0	5	98	105	8.198
41	6	0 2 0	5	104	105	8.513
41	8	0 2 0	5	83	105	6.692
41	10	0 1 0	5	94	105	7.907
41	11	0 1 0	5	87	90	7.182
41	11	0 4 0	5	14	15	1.286
41	12	0 1 0	5	91	105	7.609
41	13	0 3 0	5	103	104	8.265

*** WMS SUMMARY COMPLETE

STANDARD TIME FROM WORK MEASUREMENT

JOB NUMBER	PROD + PROD SUPPORT OBS.	TOTAL OBS.	PERCENTAGE P	RELATIVE ACCURACY	AVG MAN HRS.	TOTAL OUTPUT (PARTS)	STD. TIME (MIN.)	STD. OUTPUT (PARTS/HOUR)
0 2 0	378	417	.91	± 3.1 %	30.680	3335	.552	109
0 1 0	272	300	.91	± 3.7 %	22.698	4550	.299	200
0 3 0	103	104	.90	± 1.9 %	8.265	1500	.331	181