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AN ANALYSIS OF SOME DIFFERENCES
BETWEEN ONE AND TWO-HANDED
INDUSTRIAL WORK

Ischinger

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AN ANALYSIS OF SOME DIFFERENCES BETWEEN
ONE AND TWO-HANDED INDUSTRIAL WORK

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A Thesis

Submitted to the Faculty

of

Purdue University

by

Eric Ischinger Jr. [1921 -]

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

in

Industrial Engineering

June, 1950

AN ANALYSIS OF SOME MECHANICAL SYSTEMS
AND TWO-HARMONIC LINEAR SYSTEMS

Thesis
1964
A Thesis

Submitted to the Faculty

of

Purdue University

by

Eric J. LeBlond, Jr.

In partial fulfillment of the

Requirements for the degree

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Master of Science

in

Industrial Engineering

June, 1964

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The author wishes to express his gratitude to the many persons who have contributed much of their time and effort in making this study possible.

Much credit is due Professors H. T. Amrine and W. J. Richardson for their valuable advice, suggestions, and encouragement. It was through them also that access was gained into the plants in which the studies were made.

The author is indebted to the Colgate-Palmolive-Peet Company, Jeffersonville, Indiana, the Duncan Electric Company, Lafayette, Indiana, and the Stephen A. Young Company, Flora, Indiana, for making available their personnel and facilities. Sincere appreciation is extended to the personnel, both in the offices and the shops, for their assistance and cooperation without which this study would not have been possible.

ACKNOWLEDGEMENT

The author wishes to express his appreciation to the many persons who have contributed much to their time and effort in making this study possible.

Special credit is due Professor G. T. Swain and W. E. Richardson for their valuable advice, suggestions, and encouragement. It was through them also that access was gained into the plants in which the studies were made.

The author is indebted to the following companies for their cooperation, advice, and facilities: the Niagara A. Young Company, West, Indiana; the American Electric Company, Lafayette, Indiana; and the American Electric Company, Ellettsville, Indiana. His more appreciation is extended to the personnel who have aided him in the office and the shops for their assistance and cooperation without which this study would not have been possible.

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The purpose of this report is to determine the effect of the concentration of a solution on the rate of reaction. The reaction studied is the reaction between hydrogen peroxide and potassium iodide in the presence of a catalyst. The rate of reaction is measured by the volume of oxygen gas evolved over a period of time. The results show that the rate of reaction increases with the concentration of the hydrogen peroxide solution. This is expected since a higher concentration of reactants leads to a higher frequency of collisions between the molecules, resulting in a faster reaction rate. The data obtained from the experiment are presented in the table below.

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ABSTRACT

In the system of stop watch time study advanced by Dr. M. E. Mundel¹ the rating of an operator's performance is based upon a comparison between the pace or rate of activity of the operator and a standard rate of activity. A correction is then applied for what are now termed allowances and secondary adjustments.² One of these secondary adjustments is made for bimanualness or bimanual activity. For the purpose of this discussion a bimanual operation is defined as one requiring the simultaneous symmetrical motion of both hands.

Previous studies³ conducted at the University of Iowa show a difference in cycle time between one and two handed operations of approximately 30%. The adjustment now applied for bimanual activity is 10% based on the above figure tempered by judgement and experience in application. It was the purpose of this study to substantiate the previous research in part and to determine a more nearly correct value for this adjustment.

It was intended in this experiment to minimize the

-
1. M. E. Mundel, Systematic Motion and Time Study; (New York, Prentice Hall, 1947) p. 128.
 2. M. E. Mundel, Motion and Time Study Principles and Practice; (New York, Prentice Hall, 1950) Chapter 18 (Manuscript before press.)
 3. R. M. Barnes, M. E. Mundel, and J. M. MacKenzie, "Studies of One and Two-Handed Work," (University of Iowa Studies in Engineering, Bulletin 21, 1940).

In the system of stop watch time study introduced by Dr. H. E. Mumford, the rating of an operator's performance is based upon a comparison between the pace or rate of activity of the operator and a standard rate of activity. A correction is then applied for what are now termed allowances and secondary adjustments. One of these secondary adjustments is made for dissimilarity of physical activity. For the purpose of this discussion a dissimilarity operation is defined as one requiring the simultaneous symmetrical motion of both hands.

Previous studies conducted at the University of Iowa show a difference in cycle time between one and two handed operations of approximately 50%. The adjustment now applied for dissimilarity activity is based on the above figures tempered by judgment and experience in application. It was the purpose of this study to substantiate the previous research in part and to determine a more nearly accurate value for this adjustment.

It was intended in this experiment to maintain the

1. H. E. Mumford, Systematic Motion and Time Study; (New York, Prentice Hall, 1937) p. 125.

2. H. E. Mumford, Motion and Time Study Principles and Practice; (New York, Prentice Hall, 1905) Chapter 10 (Manuscript before press.)

3. H. E. Larson, H. E. Mumford, and J. H. Goodwin, "Studies of One and Two-Handed Work," (University of Iowa Studies in Engineering, Bulletin No. 1940).

error in the previous laboratory study believed attributable to inexperience and laboratory conditions. For that reason the subjects in this study were experienced operators doing industrial jobs requiring bimanual activity. A total of eight operators on five different operations were selected. Each operator performed the operation first bimanually, then with the preferred hand alone and finally with the non-preferred hand. A short practice period was included between each phase.

Each study was recorded on 16 mm. motion picture film with time included by means of having a microchronometer placed in the field of view. This procedure made possible a very accurate determination of cycle time. A sufficient number of cycles were photographed to obtain a statistically reliable mean cycle time for each operation.

From the mean of the cycle times there was calculated a percent increase in cycle time required for bimanual activity over that required using the preferred hand. The mean percent increase in cycle time was found to be 17.852%. Since the percent increase in cycle time is symmetrically distributed about the mean, the mean is the best measure of central tendency.⁴ It is concluded then that a value of 18% is more nearly the correct adjustment to be applied for bimanualness.

4. P. G. Hoel, Introduction to Mathematical Statistics; (New York, Wiley and Sons, Inc., 1947) p. 8, 18.

error in the previous laboratory study believed attributable to inexperience and laboratory conditions. For that reason the subjects in this study were experienced operators doing industrial job requiring manual activity. A total of eight operators on five different operations were selected. Each operator performed the operation three times, first when the product had time and finally when the product had no time. In each position period the standard deviation was measured. This study was repeated on 10 cm. section because this with time included by means of testing - at cross-sections along in the field of view. This procedure made possible a very accurate determination of cycle time. A sufficient number of cycles were photographed in order to obtain a sufficient number of cycles from each operator. From the mean of the cycle times there was calculated a percent increase in cycle time required for manual activity over that required using the product band. The mean percent increase in cycle time was found to be 37.80%. Since the percent increase in cycle time is symmetrically distributed about the mean, the mean is the best measure of central tendency. It is concluded that had a value of 100% in cycle time the correct adjustment to be applied in the plant.

AN ANALYSIS OF SOME DIFFERENCES BETWEEN
ONE AND TWO-HANDED INDUSTRIAL WORK

INTRODUCTION

"Stop watch time study is used to find the amount of time necessary to accomplish a unit of work using a given method under given conditions of work, by a worker possessing a specified amount of skill on the job and a specified aptitude for the job, when working at a pace that will produce, within a unit of time, a specified physical effect upon him."¹

There are four principal steps in the mechanics of taking a stop watch time study, namely:

1. Recording the method.
2. Recording the time.
3. Rating the operator.
4. Application of allowances and secondary adjustments.

It is a very small portion of the fourth step listed which is the subject of this study.

In the system of stop watch time study² advanced by Dr. M. E. Mundel, rating, which is the third step mentioned in the preceding paragraph, is accomplished by relating

1. Mundel, Systematic, p. 128.

2. Ibid.

AN ANALYSIS OF SOME TIME-AND-MOTION STUDIES

ONE AND TWO-MANDED INDUSTRIAL WORK

INTRODUCTION

"Stop watch time study is used to find the amount of time necessary to accomplish a unit of work under a given method under given conditions of work, by a worker possessing a specified amount of skill or the job has a specified aptitude for the job, when working at a rate that will produce, within a unit of time, a specified quantity of product, within a unit of time, a specified quantity of product upon him."

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In the system of stop watch time study, advanced by Mr. L. B. Lumsden, rating, which is the third step mentioned in the preceding paragraph, is accomplished by relating

1. Lumsden, L. B., *Systematic*, p. 128.

2. *Ibid.*

the performance of an operator to a standard by a comparison of pace alone. The fallacy of such a system without secondary adjustments for job difficulty is apparent when one considers the following exaggerated case. Suppose the rate of activity of a worker handling fifty pound weights is compared to that of a man dealing cards as a standard. Due to job difficulty the pace at which the former works cannot possibly approach that rate of activity which is the standard. An adjustment is therefore made to the rating for the degree of job difficulty - in this case the weight handled. In a like manner, but to a lesser degree, an adjustment must be made for bimanual activity.

In studies³ conducted at Iowa University there was found to be an increase in cycle time of approximately 30% when performing a simple operation bimanually over that needed to perform the operation with only one hand. From experience in the application of the adjustment for bimanualness it has been determined that a value of 30% is too great and an adjustment of 10% is now being used.

An examination of the Iowa studies suggests that the error believed to be included in the results might be attributed to a lack of experience on the part of the operators. The operators were students whose performances were recorded after a minimum of training. Equal training or practice periods were allocated to each phase of

3. Barnes, Mundel, MacKenzie, Op. Cit.

The performance of an operator in a secondary task is...
not of great importance. The failure of such a system...
secondary adjustments for job difficulty is apparent...
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low to job difficulty. The case at which the...
operator adjusts his rate of activity when...
for the degree of job difficulty - in fact...
himself. In a first experiment, but to a...
adjustment may be made for physical activity.

In studies² conducted at Iowa University...
found to be an increase in rate of activity...
when performing a single operation...
needed to perform the operation with...
experience in the application of the...
sometimes it has been determined that...
too great and an adjustment of 10% in...
an examination of the low...
error believed to be included in the...
attributed to a lack of experience...
operator. The operators were...
were recorded after a minimum of...
lay on... were allocated to each phase of

the study. The operators performed the operation first with only one hand and then bimanually. Although the operation was a relatively simple one, it is possible that a marked degree of proficiency was attained using only one hand and that the same degree of proficiency was not reached in the bimanual operation.

For study. The operators performed the possible tests
 with only one hand and their binocularly. Although the
 operation was a relatively simple one, it is possible that
 a method beyond of reliability was attained using only one
 hand and that the same degree of proficiency was not reached
 in the binocular operation.

The results of the study are summarized in the following
 table. The first column shows the type of operation, the second
 column the number of operations performed in the study,
 the third column the number of operations performed in the
 control study, and the fourth column the number of operations
 performed in the study with the binocular operation. The
 results show that the number of operations performed in the
 study with the binocular operation was significantly higher
 than the number of operations performed in the control study.
 This indicates that the binocular operation is more efficient
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 binocular operation is more efficient than the control operation.

PURPOSE

The purpose of this investigation is to determine the adjustment for bimanualness which should be applied in making a stop watch time study when using a pace-rating system.

The purpose of this investigation is to determine the
adjustment for differences which should be applied in
the study which time study when using a piece-work system.

PROCEDURE

This experiment was designed primarily to eliminate lack of experience as a factor influencing the results. Operators were selected who had considerable experience or who demonstrated the equivalent in aptitude and proficiency on bimanual jobs in industry. It appears reasonable to conclude that these operators must possess equal skill in using only one hand separately to do the identical job. Any lack of familiarity or awkwardness in performing the job with one hand was minimized by allowing short practice periods for the operators.

In addition it was intended to minimize all variables except those which are uniquely attributable to bimanual activity. Jobs were selected which required a minimum of eye-hand coordination in order to minimize the effect of that variable for which a separate correction is made. The weights of parts handled by the operator were negligible and no part of the cycle was machine paced. It might appear that a wide range of job cycle times is desirable for a study of this kind. However, all but two jobs selected had comparatively short cycle times. A short cycle was characteristic of the jobs from which the selection for this study was made and is typical of a wide variety of bimanual jobs. Eight operators on five different jobs were selected.

Once the operator was selected, the purpose, procedure

EXPERIMENT

This experiment was designed primarily to investigate lack of experience as a factor influencing the results. Operators were selected who had considerable experience and demonstrated the equivalent in aptitude and proficiency on simulated jobs in industry. It appears reasonable to conclude that these operators must possess equal skill in using only one hand separately to do the identical job. Any lack of facility or awkwardness in performing the job with one hand was minimized by allowing each practice period for the operators.

In addition it was intended to maintain all variables except those which are naturally attributable to simulated activity. Jobs were selected which required a minimum of eye-hand coordination in order to obtain the effect of that variable for which a separate operation is made. The weights of parts handled by the operator were negligible and no part of the cycle was machine work. It might appear that a wide range of job cycle times is desirable for a study of this kind. However, all but two jobs selected had comparatively short cycle times. A study was conducted of the jobs from which the selection for this study was made and is typical of a wide variety of simulated jobs. Eight operators on five different jobs were selected.

Once the operator was selected, the purpose, procedure

and scope of the study were explained to him. He was instructed to perform each phase of the study using exactly the same method and at the maximum pace which he could attain. He was assured that the motion pictures would not be used by the company in setting standards or in any way which would affect the job either directly or indirectly. The operator was given an opportunity to ask any questions he wished concerning the procedure and objectives of the study. In that way it was attempted to obtain the complete confidence and cooperation of the operator before the study was begun.

The operator first performed the operation bimanually, then with the preferred hand, and finally with the non-preferred hand. A brief practice period was allocated between each phase to enable the operator to become adapted to performing the operation with only one hand. The operator's performance was recorded using a motion picture camera. A sufficient number of cycles were photographed to insure a statistically reliable average cycle time.

The motion pictures were taken on Eastman Kodak Super XX film at 16 frames per second using an Eastmen Kodak Cine Special 16 mm. camera with an f 1.9 lens. Photoflood lights were used to supplement the light normally available to the worker in order to insure satisfactory exposures. A microchronometer was placed in the field of view of the camera in order to provide a measure of time on the film. The film is available for reference in the Motion and Time

and scope of the study were explained to him. He was in-
 structed to perform each phase of the study using exactly
 the same method and at the maximum pace which he could at-
 tain. It was ensured that the motion picture camera could not
 be used by the company in setting standards or in any way
 which would affect the job either directly or indirectly.
 The operator was given an opportunity to ask any questions
 he wished concerning the procedure and objectives of the
 study. In case any of the operator's questions were not
 satisfactorily answered and especially if the operator desired the
 study was begun.

The operator first performed the operation manually,
 then with the prepared hand, and finally with the non-
 prepared hand. A brief practice period was allowed be-
 fore each phase to enable the operator to become adjusted
 to performing the operation with only one hand. The op-
 erator's performance was recorded using a motion picture
 camera. A sufficient number of cycles were photographed
 to insure a statistically reliable average cycle time.
 The motion pictures were taken on Eastman Kodak Super
 8 film at 16 frames per second using an Eastman Kodak
 Cine Royal 16 mm. camera with an f. 8 lens. Reflected
 lights were used to supplement the light normally available
 to the worker in order to insure satisfactory exposures.
 A microprojector was placed in the field of view of the
 camera in order to provide a measure of time on the film.
 The film is available for reference in the motion picture

Study Laboratory, Purdue University.

After the film was processed, it was analyzed. For this work, a small, inexpensive, hand-crank operated motion picture projector was used to view the film in a darkened room. The projector was fitted with a heat dispensing adaptor in order that a single frame could be viewed for any length of time without danger of burning the film. The analysis consisted of determining and recording the time required for each cycle. Those cycles were not included which incorporated fumbles or irregularly occurring elements not inherent in the operation. The procedure used in analyzing the film was to pick out a well defined therblig⁴ in the operation and record the time value shown on the microchronometer each time that therblig occurred. The difference between the successive time values becomes the cycle time which was computed and recorded.

4. Mundel, Systematic, p. 105.

study laboratory, Kansas University. After the film was processed, it was analyzed. This work, a series, intensive, and-terms worked series. Various projector was used to view the film in a dark room. The projection was fitted with a good illumination system in order that a single frame could be viewed for any length of time without danger of burning the film. The analysis consisted of determining and recording the time required for each cycle. These cycles were not analyzed which transferred images or irregularly occurred images not inherent in the operation. The procedure used in analyzing the film was as follows: a well defined boundary in the operation and record the time value shown on the chronometer each time that starting occurred. The difference between the recorded time value becomes the cycle time which was recorded and recorded.

The following is a description of the apparatus used in this study. The apparatus consisted of a projector, a camera, and a film. The projector was a standard 16mm projector. The camera was a standard 16mm camera. The film was a standard 16mm film. The projector and camera were mounted on a tripod. The film was held in a film holder. The projector and camera were focused on the film. The film was then projected onto a screen. The camera was used to take pictures of the film as it was projected. The pictures were then developed and printed. The pictures were then analyzed. The analysis consisted of determining the time required for each cycle. These cycles were not analyzed which transferred images or irregularly occurred images not inherent in the operation. The procedure used in analyzing the film was as follows: a well defined boundary in the operation and record the time value shown on the chronometer each time that starting occurred. The difference between the recorded time value becomes the cycle time which was recorded and recorded.

DATA

The data for this study consists of a tabulation of the cycle times required by each operator to perform his particular operation bimanually, with the preferred hand, and with the non-preferred hand. These tables, Tables 3 through 10, and job descriptions, Figures 3 through 7, appear in the Appendix.

In each case a sufficient number of cycles were photographed to obtain a statistically reliable mean cycle time for each set of data. In order to substantiate this, one has only to apply the formula:⁵

$$N' = \left(\frac{40\sqrt{N\sum t^2 - (\sum t)^2}}{\sum t} \right)^2$$

where,

N^1 = the number of cycles required to establish the probability that 95 times out of 100 the average cycle time will be within $\pm 5\%$ of the true average representing the observed performance.

N = the number of cycles recorded.

t = the individual cycle times.

For each set of data N^1 was found to be smaller than N , and thus the reliability of the mean at the 5% level was established. The 5% confidence level is an industrially

5. M. E. Mundel, "How Many Readings in a Time Study," ("Modern Management" August, 1949).

The data for this study consist of a number of
 the cycle times recorded by each operator in various
 positions operation diameters, with the operator's
 and with the non-physical head. These data, Tables
 through 10, and job descriptions, Figures 1 through 7,
 appear in the Appendix.

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 graphed to obtain a statistically reliable mean cycle time
 for each set of data. In order to subordinate this, one
 has only to apply the formula:

$$N' = \left(\frac{40 \sqrt{N \pm 5} - (Z \pm 5)}{Z \pm 5} \right)^2$$

where
 N' = the number of cycles required to establish the
 probability that 95 times out of 100 the aver-
 age cycle time will be within 1% of the true
 average representing the observed performance.

N = the number of cycles recorded.
 t = the individual cycle times.
 For each set of data N' was found to be smaller than N, and
 thus the reliability of the mean at the 95 level was as-
 sured. The 95 confidence level is an industrially

W. H. Wood, "The New Handbook in Time Study",
 "Industrial Management", August, 1940.

accepted standard. For mathematical computations see
Table 11.

see mathematical computations see

Table II.

The following table shows the results of the calculations for the various cases. The first column gives the value of the parameter α , the second column the value of the function $f(\alpha)$, and the third column the value of the derivative $f'(\alpha)$. The values of $f(\alpha)$ and $f'(\alpha)$ are given to four decimal places.

$$f(\alpha) = \frac{1}{2} \left(\frac{1}{\alpha} + \frac{1}{\alpha^2} \right)$$

The values of $f(\alpha)$ and $f'(\alpha)$ are given to four decimal places. The values of $f(\alpha)$ are given to four decimal places. The values of $f'(\alpha)$ are given to four decimal places. The values of $f(\alpha)$ are given to four decimal places. The values of $f'(\alpha)$ are given to four decimal places.

RESULTS

The mean cycle time required by each operator for each phase of the operation is recorded in Table 1.

Table 1
MEAN JOB CYCLE TIMES. \bar{t}

Oper- ation	Oper- ator	Mean Cycle Time (winks)		
		Bi- manually	Preferred Hand	Non-preferred Hand
1	1	36.000	30.893	31.710
	2	34.333	28.210	28.270
	3	40.133	33.051	33.088
2	1	34.895	30.463	31.571
	2	45.357	35.000	40.533
3	1	41.621	38.147	40.625
4	1	250.167	222.818	222.000
5	1	177.452	150.850	156.667

A wink is a 1/2000th part of a minute.

From the above results there was computed the percent increase in cycle time required when performing bimanually and when using the non-preferred hand over that required when using the preferred hand. That information is shown in Table 2.

RESULTS

The mean cycle time required by each operator for each phase of the operation is recorded in Table I.

Table I
MEAN CYCLE TIME

Operator	Operator	Mean Cycle Time (mins)	Operator	Operator
1	2	3	4	5
31.77	30.98	28.00	1	1
28.27	28.21	24.25	2	
33.08	33.01	40.15	3	
31.81	30.48	24.98	1	2
40.88	33.00	28.27	2	
40.82	38.17	41.81	1	3
32.00	32.12	20.17	1	4
30.87	33.88	17.42	1	5

A week is a 1/200th part of a minute.

From the above results there was computed the increase in cycle time required when performing irregularly and when using the non-reversed hand over that required when using the preferred hand. This information is shown in Table 2.

Table 2

PERCENT INCREASE IN CYCLE TIME
OVER PREFERRED HAND TIMES

Operation	Operator	Bimanually	Non-Preferred Hand
1	1	16.531	2.645
	2	21.705	0.213
	3	21.427	0.112
2	1	14.549	3.637
	2	29.591	15.808
3	1	9.107	6.496
4	1	12.274	-0.368
5	1	17.635	3.856

The mean percent increase in cycle time for bimanual operation over that required using the preferred hand alone is determined from the above to be 17.852%.

Table 2

PERCENT INCREASE IN CYCLE TIME
OVER PREVIOUS YEAR

Year	Operation	Operation	Year
1951	1	1	1951
1952	2	2	1952
1953	3	3	1953
1954	4	4	1954
1955	5	5	1955
1956	6	6	1956
1957	7	7	1957
1958	8	8	1958
1959	9	9	1959

The mean percent increase in cycle time for bimodal operation over that reported using the preferred beam alone is determined from the above to be 17.55%.

DISCUSSION OF RESULTS

Since the cycle times in two of the eight jobs studied were comparatively long, it was believed desirable to see what effect, if any, the length of cycle time had upon the percent increase in cycle time. A simple correlation coefficient between the two was calculated using the formula:

$$r = \frac{N\sum XY - \sum X \sum Y}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}}$$

$$= 0.34$$

This correlation coefficient is not significantly different from zero and, therefore, there is little correlation between the two items. To further substantiate this result a line of least squares was calculated for this data and was found to have a slope of +.029. The scattergram for this data is shown in Figure 1. For mathematical computations see Table 12.

A histogram showing the frequency distribution of the percent increase in cycle times in the class intervals 0-5%, 5-10%, 10-15%, 15-20%, 20-25% and 25-30% is shown in Figure 2. It is clearly evident that the observed values are quite symmetrically distributed about the mean which was found to be 17.852% and that, therefore, the mean value is the best measure of central tendency.⁶

6. Hoel, loc. cit.

DISCUSSION OF RESULTS

Since the cycle times in two of the other days studied were comparatively long, it was believed desirable to see what effect, if any, the length of cycle time had upon the percent increase in cycle time. A simple correlation coefficient between the two was calculated using the formula:

$$r = \frac{\sum (x_1 - \bar{x}_1)(x_2 - \bar{x}_2)}{\sqrt{\sum (x_1 - \bar{x}_1)^2 \sum (x_2 - \bar{x}_2)^2}}$$

= 0.54

This correlation coefficient is not statistically different from zero and, therefore, there is little correlation between the two items. The further significance test results a line of least squares was calculated for this data and was found to have a slope of +.017. The scattergram for this data is shown in Figure 1. For statistical comparison see Table 12.

A histogram showing the frequency distribution of the percent increase in cycle times in the other inventories 0-5%, 5-10%, 10-15%, 15-20%, 20-25% and 25-30% is shown in Figure 2. It is clearly evident that the observed values are quite symmetrically distributed about the mean value and found to be 17.34% and that, therefore, the mean value is the best measure of central tendency.

This value of 18% is clearly significantly different from the 30% which was previously found in the Iowa studies.⁷ It is indeed probable that the major contributing factor to that difference is the inexperience of the operators in the previous experiment. That factor has been minimized in the present study. It is concluded that the 18% increase in cycle time is due almost entirely to what might be termed difficulty of coordination in bimanual activity.

7. Barnes, Mundel, and McKenzie, op. cit.

This value of 10^4 is already significantly different
 from the value previously found in the literature
 and it is rather probable that the major contribution
 to the total activity is due to the presence of the
 species in the previous experiment. The total and
 individual activities are shown in Figure 1. It is noted that the
 total activity in equilibrium is one half of the activity in
 Figure 1. It is noted that the activity in equilibrium is
 significantly different from the activity in Figure 1.

Activity

Activity



CONCLUSIONS

Since it has been shown that an average operator requires 18% longer to complete a cycle bimanually than when using only one hand, it follows that he must be operating at a pace 18% slower in the former case. Yet in each case he was performing at a rate of activity which represented his maximum effort. Therefore, the rating assigned to the operators performance should be identical in both instances. Using pace alone as a criterion, however, the operator when performing bimanually would be rated 18% lower than when using only the preferred hand. To make the ratings identical, a correction of 18% must be added to the rating assigned to the bimanual operation. Therefore, it is concluded that a secondary adjustment of 18% must be made to compensate for job difficulty in bimanual operations using a pace-rating system of time study.

CONCLUSIONS

It has been shown that an average operator performs better than a group of operators in a task which is normally done by a single operator. It follows that the best performance is obtained when the operator is alone in the control room. It is also shown that the performance of a group of operators is not as good as that of a single operator. It is concluded that a necessary adjustment of the task must be made to compensate for the difficulty in manual operations when a processing system of time study.

APPENDIX

The first part of the report deals with the general situation of the country and the progress of the work done during the year. It is followed by a detailed account of the various projects and schemes which have been carried out. The report then goes on to discuss the financial position of the organization and the results of the various committees and sub-committees. Finally, it concludes with a summary of the work done and a list of the names of the members of the organization.

APPENDIX

The following table shows the names of the members of the organization who have been elected to office during the year. It is divided into two columns, one for the names of the members and the other for the names of the offices which they have held.

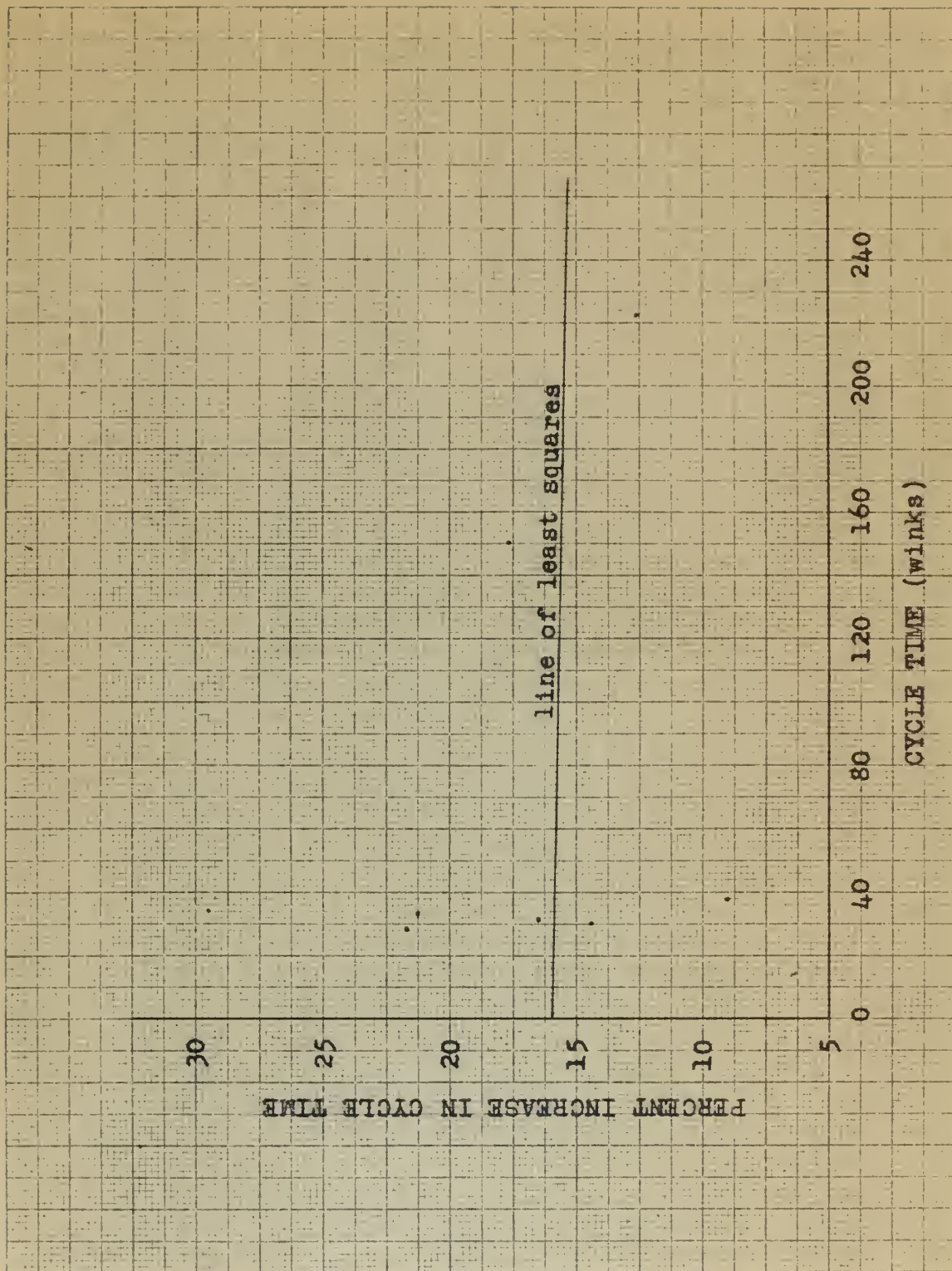


Figure 1. Mean cycle time vs. percent increase in cycle time for bimanual over preferred hand activity.

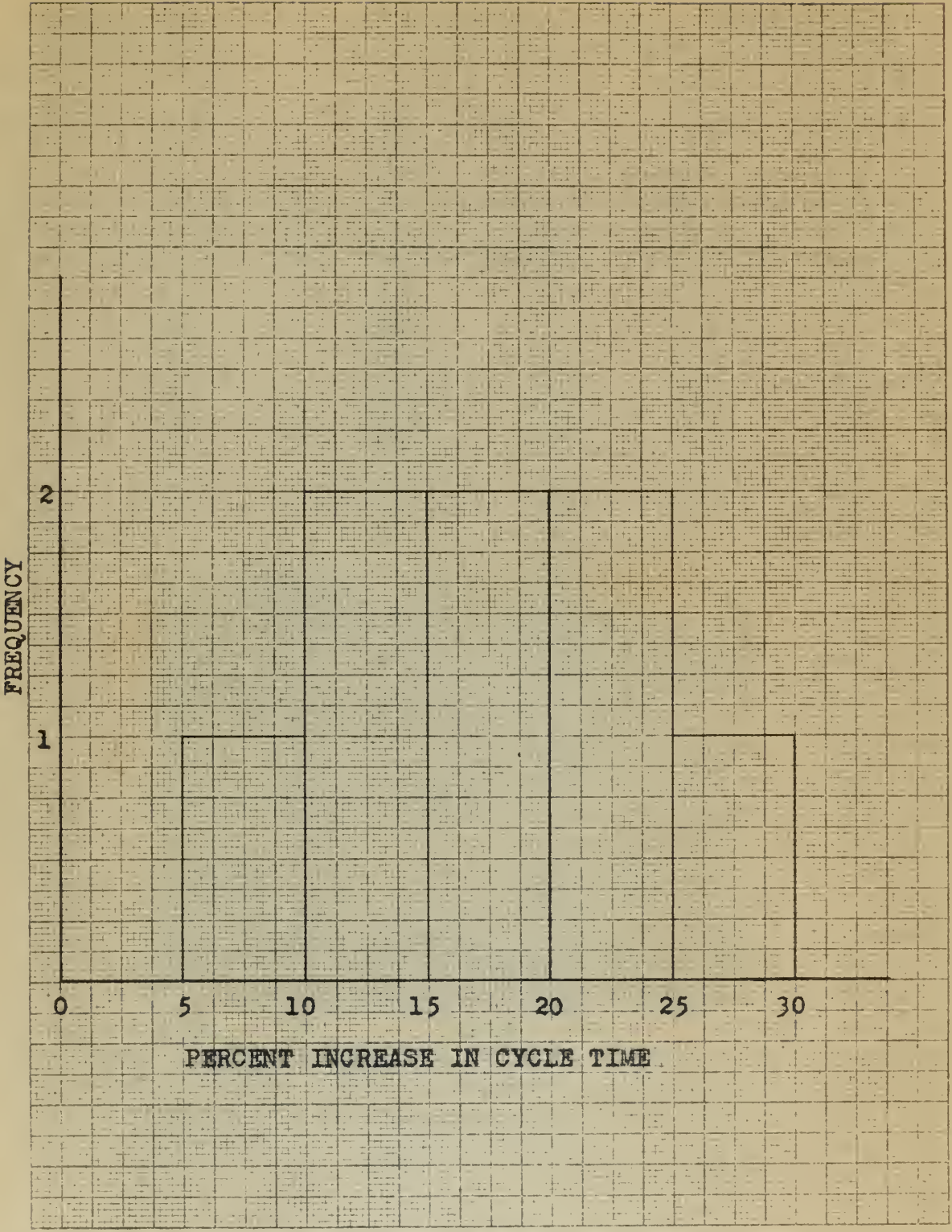


Figure 2. Histogram showing frequency distribution of percent increase in mean cycle time.

Operation: Filling carton with individual boxes of Veto.

Left Hand	Description	Right Hand
Get box of Veto	TE, <u>G</u> , TL	Get box of Veto
Place in carton	P, A, RL	Place in carton

The therblig underlined performed by the right hand is the beginning of the cycle for the purposes of this time analysis.



Figure 3. Workplace for Packaging Veto.

Operation: Willing person who holds the boxes of tape.

Right Hand	Operation	Left Hand
Get box of tape	Transfer	Get box of tape
Place in system	Transfer	Place in system

The transfer operation is performed by the right hand in the
 direction of the tape for the purpose of this time study.

via



Figure 3. Sample for transfer study.

Table 3
VETO PACKAGING #1

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
595		315		784	
630	35	369*		814	30
675	35	013*		845	31
768*		049	36	876	31
806	38	573*		911	35
919*		566	29	132*	
954	35	616*		165	33
000*		665*		200	35
036	36	697*		247*	
069	33	728	31	273	26
230*		867*		300	27
267	37	897	30	330	30
307	40	955*		373*	
351*		030*		411*	
385	34	068*		543	32
423	38	100	32	575	32
572*		144*		606	31
612*		171	27	640	36
650	38	205	34	675	35
682	32	235	30	703	28
729*		265	30	734	31
840*		302	37	761	27
872	32	393*		793	32
912	40	434*		827	34
950	38	464	30	860	33
978	28	575*		022*	
026*		548	33	050	28
315*		574	26	078	28
350	35	620*		116*	
386	36	650	30	154*	
516*		680	30	185	31
601*		710	30	236*	
642	41	740	30	267	31
855*		771	31	300	33
895	40	848*		332	32
940*		888*		074*	
975	35	920	32	413*	
011	36	960*		549*	
		996	36	583	34
		024	28	615	32
		056	32	650	35
		086	30	685	35
		130*		720	35
		160	30	752	32
		193	33	780	28
		226	33	812	32
		323*		840*	
		351	28	871	31
		378	27	046*	
		415*		078	32
				111	33
				150*	
				188*	
				222	34

Σt	792	865	1205
N	22	28	38
\bar{t}	36.000	30.893	31.710

T = elapsed time, t = cycle time, N = number of cycles
 \bar{t} = mean cycle time. Note: Symbols apply to Tables 3 - 10.
 *Cycle time not included because of fumble or irregularly occurring element.

Table 4
 1950-1959

1950-1959		1950-1959		1950-1959	
1	2	1	2	1	2
10	104		104		104
11	105		105		105
12	106		106		106
13	107		107		107
14	108		108		108
15	109		109		109
16	110		110		110
17	111		111		111
18	112		112		112
19	113		113		113
20	114		114		114
21	115		115		115
22	116		116		116
23	117		117		117
24	118		118		118
25	119		119		119
26	120		120		120
27	121		121		121
28	122		122		122
29	123		123		123
30	124		124		124
31	125		125		125
32	126		126		126
33	127		127		127
34	128		128		128
35	129		129		129
36	130		130		130
37	131		131		131
38	132		132		132
39	133		133		133
40	134		134		134
41	135		135		135
42	136		136		136
43	137		137		137
44	138		138		138
45	139		139		139
46	140		140		140
47	141		141		141
48	142		142		142
49	143		143		143
50	144		144		144
51	145		145		145
52	146		146		146
53	147		147		147
54	148		148		148
55	149		149		149
56	150		150		150
57	151		151		151
58	152		152		152
59	153		153		153
60	154		154		154
61	155		155		155
62	156		156		156
63	157		157		157
64	158		158		158
65	159		159		159
66	160		160		160
67	161		161		161
68	162		162		162
69	163		163		163
70	164		164		164
71	165		165		165
72	166		166		166
73	167		167		167
74	168		168		168
75	169		169		169
76	170		170		170
77	171		171		171
78	172		172		172
79	173		173		173
80	174		174		174
81	175		175		175
82	176		176		176
83	177		177		177
84	178		178		178
85	179		179		179
86	180		180		180
87	181		181		181
88	182		182		182
89	183		183		183
90	184		184		184
91	185		185		185
92	186		186		186
93	187		187		187
94	188		188		188
95	189		189		189
96	190		190		190
97	191		191		191
98	192		192		192
99	193		193		193
100	194		194		194

Table 4
VETO PACKAGING #2

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
210*		380		745	
253*		406	26	770	25
293	40	456*		793	23
327	34	509*		818	25
377*		535	26	847	29
473*		558	23	860*	
510	37	591	33	885	25
549	39	621	30	055*	
587	38	652	31	095*	
622	35	743*		125	30
658	36	770	27	158	33
753*		797	27	183	25
792	39	830	33	208	25
830	38	865	35	245	37
869	39	897	32	269	24
911*		936*		294	25
948	37	964	28	376*	
033*		985	21	405	29
065	32	008	23	434	29
099	34	037	29	463	29
158*		059*		493	30
187	29	092	33	528	35
218	31	192*		560	32
300*		220	28	586	26
334	34	968*		612	26
376*		352*		640	28
410	34	380	28	668	28
442	32	411	31	695	27
469	27	436	25	787*	
550*		460	24	826*	
580	30	490	30	856	30
622*		520	30	885	29
659	37	552	32	966*	
693	34	638*		005*	
728	35	664	26	034	29
825*		690	26	067	33
857	32	740*		110*	
895	38	785*		148*	
934	39	828*		177	29
962	28	867*		296*	
990	28	946*		225	29
083*		974	28	254	29
122	39	998	24	284	30
157	35	085*		324*	
193	36	111	26	452	28
223	30	142	31	480	28
250	27	172	30	507	27
		202	30	532	25
		234	32	557	25
		264	30	587	30
		291	27		
		317	26		
		361*			
		386	25		
		412	26		
Σt	1133	1072		1046	
$\frac{N}{t}$	33	38		37	
\bar{t}	34.333	28.210		28.270	

*Cycle time not included because of fumble or irregularly occurring element.

1950
 DEPARTMENT OF THE ARMY
 OFFICE OF THE ADJUTANT GENERAL

1950		1951		1952	
1	2	1	2	1	2
01	01	01	01	01	01
02	02	02	02	02	02
03	03	03	03	03	03
04	04	04	04	04	04
05	05	05	05	05	05
06	06	06	06	06	06
07	07	07	07	07	07
08	08	08	08	08	08
09	09	09	09	09	09
10	10	10	10	10	10
11	11	11	11	11	11
12	12	12	12	12	12
13	13	13	13	13	13
14	14	14	14	14	14
15	15	15	15	15	15
16	16	16	16	16	16
17	17	17	17	17	17
18	18	18	18	18	18
19	19	19	19	19	19
20	20	20	20	20	20
21	21	21	21	21	21
22	22	22	22	22	22
23	23	23	23	23	23
24	24	24	24	24	24
25	25	25	25	25	25
26	26	26	26	26	26
27	27	27	27	27	27
28	28	28	28	28	28
29	29	29	29	29	29
30	30	30	30	30	30
31	31	31	31	31	31
32	32	32	32	32	32
33	33	33	33	33	33
34	34	34	34	34	34
35	35	35	35	35	35
36	36	36	36	36	36
37	37	37	37	37	37
38	38	38	38	38	38
39	39	39	39	39	39
40	40	40	40	40	40
41	41	41	41	41	41
42	42	42	42	42	42
43	43	43	43	43	43
44	44	44	44	44	44
45	45	45	45	45	45
46	46	46	46	46	46
47	47	47	47	47	47
48	48	48	48	48	48
49	49	49	49	49	49
50	50	50	50	50	50
51	51	51	51	51	51
52	52	52	52	52	52
53	53	53	53	53	53
54	54	54	54	54	54
55	55	55	55	55	55
56	56	56	56	56	56
57	57	57	57	57	57
58	58	58	58	58	58
59	59	59	59	59	59
60	60	60	60	60	60
61	61	61	61	61	61
62	62	62	62	62	62
63	63	63	63	63	63
64	64	64	64	64	64
65	65	65	65	65	65
66	66	66	66	66	66
67	67	67	67	67	67
68	68	68	68	68	68
69	69	69	69	69	69
70	70	70	70	70	70
71	71	71	71	71	71
72	72	72	72	72	72
73	73	73	73	73	73
74	74	74	74	74	74
75	75	75	75	75	75
76	76	76	76	76	76
77	77	77	77	77	77
78	78	78	78	78	78
79	79	79	79	79	79
80	80	80	80	80	80
81	81	81	81	81	81
82	82	82	82	82	82
83	83	83	83	83	83
84	84	84	84	84	84
85	85	85	85	85	85
86	86	86	86	86	86
87	87	87	87	87	87
88	88	88	88	88	88
89	89	89	89	89	89
90	90	90	90	90	90
91	91	91	91	91	91
92	92	92	92	92	92
93	93	93	93	93	93
94	94	94	94	94	94
95	95	95	95	95	95
96	96	96	96	96	96
97	97	97	97	97	97
98	98	98	98	98	98
99	99	99	99	99	99
00	00	00	00	00	00

Table 5
VETO PACKAGING #3

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
265*		142*		227*	
308	43	193*		251	24
347	39	246*		282	31
403*		304*		324*	
446	43	337	33	356	32
555*		376	39	566*	
590	35	426*		598	32
631	41	486*		632	34
670	39	531*		666	34
707	37	562	31	699	33
750	43	623*		742*	
837*		670*		770	28
877	40	705	35	799	29
938*		737	32	830	31
985	47	450*		863	33
049*		492	42	894	31
084	35	528	36	043*	
201*		565	37	075	32
237	36	635*		108	33
275	38	759*		142	34
346*		789	30	175	33
384	38	813	24	215	40
422	38	843	30	249	34
547*		876	33	280	31
586	39	962*		314	34
624	38	992	30	345	31
664	40	025	33	376	31
708	44	064	39	428*	
747	39	094	30	573*	
863*		130	36	613	40
900	37	172	42	666*	
938	38	202	30	696	30
977	39	237	35	736	40
015	38	270	33	767	31
054	39	300	30	804	37
166*		330	30	836	32
206	40	443*		878	42
255	49	470	27	921	43
328*		496	26	958	37
367	39	527	31	989	31
415	48	560	33	145*	
507*		596	36	174	29
552	45	628	32	202	28
		659	31	248*	
		687	28		
		715	28		
		757	42		
		782	25		
		899*			
		930	31		
		961	31		
		004	43		
		046	42		
		092*			
		125	33		
Σt	1204	1289		1125	
$\frac{N}{t}$	30	39		34	
\bar{t}	40.133	33.051		33.088	

*Cycle time not included because of fumble or irregularly occurring element.

Operation: Filling carton with individual tooth powder cans.

Description		
Left Hand	Therblig	Right Hand
Get can of tooth powder	TE, <u>G</u> , TL	Get can of tooth powder
Place in carton	P, A, RL	Place in carton

The underlined therblig performed by the right hand is the start of the work cycle for the purpose of this time analysis.



Figure 4. Workplace for tooth powder packaging.

Operation: Milling carbon with industrial grade powder.

Classification

Left Hand	Right Hand	Left Hand
Get out of floor powder 10, 15, 20	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Get out of floor powder 10, 15, 20
Place in carbon	Place in carbon	Place in carbon

The material should be removed by the right hand in the start of the work cycle for the purpose of this time study.

Mr.



Figure 4. Sequence for floor powder handling.

Table 6

TOOTH POWDER PACKAGING #1

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
602*		540*		368*	
681*		567	27	405*	
730*		619*		439	34
762	32	649	30	560*	
888*		677	28	590	30
927	39	707	30	616	26
976*		735	28	647	31
015	39	764	29	687*	
092*		795	31	718	31
123	31	822	27	761*	
255*		945*		802*	
287	32	976	31	832	30
324	37	004	28	862	30
360	36	035	31	891	29
406*		064	29	929*	
570*		095	31	036*	
601	31	124	29	076*	
635	34	155	31	110	34
670	35	192*		140	30
705	35	222	30	184*	
738	33	255	33	248*	
879*		445*		280	32
918	39	535*		330*	
952	34	570	35	372*	
023*		670*		407	35
123*		702	32	444	37
265*		734	32	475	31
295	30	762	28	611*	
330	35	793	31	645	34
377*		825	32	684*	
415	38	926*		725*	
455	40	957	31	764*	
608*		985	28	795	31
645*		017	32	827	32
686*		055*		857	30
728*		085	30	887	30
761	33	117	32	918	31
805*		147	30	953	35
926*		183	36	984	31
982*		216	33	155*	
		246	30	183	28
		288*		213	30
		425*		247	34
		454	29	287*	
		492*		318	31
		522	30	351	33
		554	32	385	34
		585	31		
		626*			
		685*			
		720	35		
		751	31		
		781	30		
		930*			
		956	26		
		986	30		
Σt	663	1249		884	
$\frac{N}{t}$	19	41		28	
\bar{t}	34.895	30.504		31.571	

*Cycle time not included because of fumble or irregularly occurring element.

Table 2: [Illegible Title]

[Illegible]		[Illegible]		[Illegible]	
1	2	1	2	1	2
100	100	100	100	100	100
95	95	95	95	95	95
90	90	90	90	90	90
85	85	85	85	85	85
80	80	80	80	80	80
75	75	75	75	75	75
70	70	70	70	70	70
65	65	65	65	65	65
60	60	60	60	60	60
55	55	55	55	55	55
50	50	50	50	50	50
45	45	45	45	45	45
40	40	40	40	40	40
35	35	35	35	35	35
30	30	30	30	30	30
25	25	25	25	25	25
20	20	20	20	20	20
15	15	15	15	15	15
10	10	10	10	10	10
5	5	5	5	5	5
0	0	0	0	0	0

Table 7

TOOTH POWDER PACKAGING #2

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
620*		425*		355*	
661	41	459	34	392	37
715*		492	33	440*	
785*		525	33	496*	
829	44	558	33	580*	
917*		593	35	625	45
052*		640*		668	43
095	43	675	35	710	42
181*		734*		765*	
245*		767	33	805	40
292	47	803	36	901*	
345*		914*		944	43
480*		947	33	985	41
525	45	980	33	024	39
572	47	018	38	065	41
635*		054	36	123*	
688*		107*		165	42
737	49	151*		206	41
862*		185	34	248	42
901	39	255*		287	39
949	48	295	40	326	39
129*		332	37	365	39
267*		370	38	482*	
310	43	485*		567*	
370*		554*		637*	
418	48	591	37	680	43
474*		627	36	727	47
522	48	666	39	767	40
647*		711*		805	38
690	43	763*		845	40
740	50	855*		885	40
		885	30	930	45
		985*		970	40
		094*		105	35
		132	38	147	42
		170	38	182	35
		197	27	230*	
		232	35	283*	
		270	38	326	43
		299	29	365	39
		345*		438*	
		382	37	490*	
		419	37	532	42
		452	33	574	42
		485	33	640	36
		584*			
		620	36		
		650	30		
		689	39		
		723*			
		760	37		
<hr/>					
Σt	635	1190		1259	
$\frac{\Sigma t}{N}$	45.357	35.000		40.533	

*Cycle time not included because of fumble or irregularly occurring element.

Table 1

Summary of the data

Group 1		Group 2		Group 3	
1	2	1	2	1	2
10	100	10	100	10	100
20	200	20	200	20	200
30	300	30	300	30	300
40	400	40	400	40	400
50	500	50	500	50	500
60	600	60	600	60	600
70	700	70	700	70	700
80	800	80	800	80	800
90	900	90	900	90	900
100	1000	100	1000	100	1000
110	1100	110	1100	110	1100
120	1200	120	1200	120	1200
130	1300	130	1300	130	1300
140	1400	140	1400	140	1400
150	1500	150	1500	150	1500
160	1600	160	1600	160	1600
170	1700	170	1700	170	1700
180	1800	180	1800	180	1800
190	1900	190	1900	190	1900
200	2000	200	2000	200	2000
210	2100	210	2100	210	2100
220	2200	220	2200	220	2200
230	2300	230	2300	230	2300
240	2400	240	2400	240	2400
250	2500	250	2500	250	2500
260	2600	260	2600	260	2600
270	2700	270	2700	270	2700
280	2800	280	2800	280	2800
290	2900	290	2900	290	2900
300	3000	300	3000	300	3000
310	3100	310	3100	310	3100
320	3200	320	3200	320	3200
330	3300	330	3300	330	3300
340	3400	340	3400	340	3400
350	3500	350	3500	350	3500
360	3600	360	3600	360	3600
370	3700	370	3700	370	3700
380	3800	380	3800	380	3800
390	3900	390	3900	390	3900
400	4000	400	4000	400	4000
410	4100	410	4100	410	4100
420	4200	420	4200	420	4200
430	4300	430	4300	430	4300
440	4400	440	4400	440	4400
450	4500	450	4500	450	4500
460	4600	460	4600	460	4600
470	4700	470	4700	470	4700
480	4800	480	4800	480	4800
490	4900	490	4900	490	4900
500	5000	500	5000	500	5000
510	5100	510	5100	510	5100
520	5200	520	5200	520	5200
530	5300	530	5300	530	5300
540	5400	540	5400	540	5400
550	5500	550	5500	550	5500
560	5600	560	5600	560	5600
570	5700	570	5700	570	5700
580	5800	580	5800	580	5800
590	5900	590	5900	590	5900
600	6000	600	6000	600	6000
610	6100	610	6100	610	6100
620	6200	620	6200	620	6200
630	6300	630	6300	630	6300
640	6400	640	6400	640	6400
650	6500	650	6500	650	6500
660	6600	660	6600	660	6600
670	6700	670	6700	670	6700
680	6800	680	6800	680	6800
690	6900	690	6900	690	6900
700	7000	700	7000	700	7000
710	7100	710	7100	710	7100
720	7200	720	7200	720	7200
730	7300	730	7300	730	7300
740	7400	740	7400	740	7400
750	7500	750	7500	750	7500
760	7600	760	7600	760	7600
770	7700	770	7700	770	7700
780	7800	780	7800	780	7800
790	7900	790	7900	790	7900
800	8000	800	8000	800	8000
810	8100	810	8100	810	8100
820	8200	820	8200	820	8200
830	8300	830	8300	830	8300
840	8400	840	8400	840	8400
850	8500	850	8500	850	8500
860	8600	860	8600	860	8600
870	8700	870	8700	870	8700
880	8800	880	8800	880	8800
890	8900	890	8900	890	8900
900	9000	900	9000	900	9000
910	9100	910	9100	910	9100
920	9200	920	9200	920	9200
930	9300	930	9300	930	9300
940	9400	940	9400	940	9400
950	9500	950	9500	950	9500
960	9600	960	9600	960	9600
970	9700	970	9700	970	9700
980	9800	980	9800	980	9800
990	9900	990	9900	990	9900
1000	10000	1000	10000	1000	10000

Source: Author's calculations

10

Operation: Filling carton with bottles of Halo.

	Description	
Left Hand	Therblig	Right Hand
Get bottle of Halo	TE, <u>G</u> , TL	Get bottle of Halo
Place in carton	P, A, RL	Place in carton

The therblig underlined performed by the right hand represents the start of a cycle for the purpose of this time analysis.



Figure 5. Workplace for Packaging Halo.

Operation: filling carton with bottles of milk.

Operation:

Right hand	Turning	Left hand
Get bottle of milk	Put $\frac{1}{2}$ in	Get bottle of milk
Place in carton	Put $\frac{1}{2}$ in	Place in carton

The charting suggested performed by the right hand represents the start of a cycle for the purpose of this line analysis.



Figure 2. Sequence for reaching milk.

Table 8

HALO PACKAGING

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
499*		872*		890*	
544	45	911	39	931	41
673*		960*		973	42
712	39	040*		040*	
756	44	085	45	090*	
795	39	124	39	132	42
835	40	257*		170	38
878	43	300	43	220*	
136*		337	37	282*	
185	49	372	35	333*	
218	33	423*		388*	
258	40	459	36	523*	
302	44	498	39	563	40
422*		540	42	610	47
460	38	578	38	652	42
502	42	624	46	717*	
542	40	664	40	757	40
582	40	699	35	808*	
628	46	828*		847	39
754*		878*		905*	
796	42	916	38	960*	
842	46	955	39	010*	
880	38	008*		065*	
920	40	046	38	227*	
979*		085	39	265	38
107*		122	37	307	42
148	41	235*		347	40
189	41	274	39	459*	
226	37	312	38	495	36
264	38	438*		540	45
310	46	474	36	575	35
417*		513	39	618	43
454	37	549	36		
528*		599*			
564	36	636	37		
603	39	673	37		
656*		711	38		
796*		748	37		
836	40	790	42		
877	41	827	37		
917	40	863	37		
960	43	003	40		
007	47	037	34		
131*		068	31		
172	41	102	34		
216	44				
263	47				
310	47				
357	47				
<hr/>					
Σt	1540	1297		650	
$\frac{N}{t}$	37	34		16	
\bar{t}	41.621	38.147		40.625	

*Cycle time not included because of fumble or irregularly occurring element.

Operation: Assembling faucet sub-assembly.

Left Hand	Description	Right Hand
Get saw	TE, G, P	Get saw
Assemble with fixture	A, RL	Assemble with fixture
Get washer	TE, G, TL	Get washer
Assemble with screw	P, A, RL	Assemble with screw
Get swivel	TE, G, P	Get swivel
Assemble with screw	A, RL	Assemble with screw
Disassemble from fixture	TE, G, TL	Disassemble from fixture
Assemble with tighten- ing board	P, <u>A</u> , RL	Assemble with tighten- ing board

The underlined Therblig represents the performed act by the right hand beginning a cycle for the purposes of this time analysis.



Figure 6. Workplace for assembling faucet sub-assemblies.

Operation: Assembly (and dis-assembly)

Right Hand	Workpiece	Left Hand
Get saw	T. G. 2	Get saw
Assemble with fixture	A. M.	Assemble with fixture
Get washer	T. G. 11	Get washer
Assemble with screw	F. A. M.	Assemble with screw
Get valve	T. G. 2	Get valve
Assemble with screw	A. M.	Assemble with screw
Disassemble from fixture	T. G. 11	Disassemble from fixture
Fixture		
Assemble with right-hand board	V. A. M.	Assemble with right-hand board

The underlined words in the above list represent the performed work of the right hand beginning a cycle for the purpose of this list analysis.



Figure 8. Workpiece for assembling (and dis-assembly).

Table 9

FAUCET SUB-ASSEMBLY

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
238*		118*		988*	
501	263	372	254	212	224
725	224	590	218	436	224
980	255	808	218	662	226
259	271	043	235	876	214
495	236	308*		160*	
759	264	511	203		
024	265	725	214		
426*		922	197		
696	270	317*			
985*		530	213		
410*		796*			
700*		035	239		
926	226	284	249		
140	214	456*			
391	251	741*			
689*		770*			
065*		981	211		
328	263				
626*					
<hr/>					
Σt	3002	2451		888	
N	12	11		4	
\bar{t}	250.167	222.154		222.000	

*Cycle time not included because of fumble or irregularly occurring element.

Table 3

FACTORY DATA SUMMARY

Plant No.		Plant Name		Plant Location	
1	2	3	4	5	6
100	100	100	100	100	100
101	101	101	101	101	101
102	102	102	102	102	102
103	103	103	103	103	103
104	104	104	104	104	104
105	105	105	105	105	105
106	106	106	106	106	106
107	107	107	107	107	107
108	108	108	108	108	108
109	109	109	109	109	109
110	110	110	110	110	110
111	111	111	111	111	111
112	112	112	112	112	112
113	113	113	113	113	113
114	114	114	114	114	114
115	115	115	115	115	115
116	116	116	116	116	116
117	117	117	117	117	117
118	118	118	118	118	118
119	119	119	119	119	119
120	120	120	120	120	120
121	121	121	121	121	121
122	122	122	122	122	122
123	123	123	123	123	123
124	124	124	124	124	124
125	125	125	125	125	125
126	126	126	126	126	126
127	127	127	127	127	127
128	128	128	128	128	128
129	129	129	129	129	129
130	130	130	130	130	130
131	131	131	131	131	131
132	132	132	132	132	132
133	133	133	133	133	133
134	134	134	134	134	134
135	135	135	135	135	135
136	136	136	136	136	136
137	137	137	137	137	137
138	138	138	138	138	138
139	139	139	139	139	139
140	140	140	140	140	140
141	141	141	141	141	141
142	142	142	142	142	142
143	143	143	143	143	143
144	144	144	144	144	144
145	145	145	145	145	145
146	146	146	146	146	146
147	147	147	147	147	147
148	148	148	148	148	148
149	149	149	149	149	149
150	150	150	150	150	150

151 151 151 151 151 151
 152 152 152 152 152 152
 153 153 153 153 153 153
 154 154 154 154 154 154
 155 155 155 155 155 155
 156 156 156 156 156 156
 157 157 157 157 157 157
 158 158 158 158 158 158
 159 159 159 159 159 159
 160 160 160 160 160 160

Notes: This table contains data for plants 1 through 160. The data is presented in a grid format with 6 columns and 160 rows. The first two columns represent plant numbers, and the remaining four columns represent various data points for each plant. The data is sorted in ascending order of plant number.

Operation: Assembling watt-hour meter sub-assembly.

Description		
Left Hand	Therblig	Right Hand
Get sleeve	TE, G, TL	Get sleeve
Assemble with fixture	P, A, RL	Assemble with fixture
Get washer	TE, G, TL	Get washer
Assemble with fixture	P, A, RL	Assemble with fixture
Get screw	TE, G, TL	Get screw
Assemble with sleeve and washer	P, A, RL <u>DA</u> , RL	Assemble with sleeve and washer
		Trip fixture release

The therblig underlined performed by the right hand represents the beginning of a cycle for the purpose of this time analysis.



Figure 7. Workplace for assembling watt-hour meter sub-assembly.

Inspection

Lot's name	Quantity	Lot's name
Get sleeve	12, 0, 12	Get sleeve
Assembly with fixture	1, 1, 12	Assembly with fixture
Get washer	12, 0, 12	Get washer
Assembly with fixture	1, 1, 12	Assembly with fixture
Get screw	12, 0, 12	Get screw
Assembly with sleeve		Assembly with sleeve
Get washer	1, 1, 12	Get washer
Get fixture release	12, 12	

The quantity indicated performed by the right hand worker
 under the beginning of a cycle for the purpose of this time
 analysis.



Figure 5. Samples for assembling
 well-head water sub-assembly.

Table 10

ASSEMBLING SLEEVE AND WASHER TO BOLT

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
750*		037*		707*	
918	168	235	198	874	167
135	217	427	192	054	180
352*		553	126	179	125
598*		740	187	316	137
788	190	867	127	483	167
009	221	135	168	645	162
152	143	255*		810	165
556*		430	175	958	148
775	219	586	156	093	135
915	140	740	154	231	138
084	169	874	136	380	149
239	155	059	185	526	146
385	146	237	178	654	128
580	195	704*		785	131
791	211	874	170	930	145
960	169	015	141	111	181
103	143	152	137	647*	
338*		304	152	867*	
496	158	456	152	996	129
656	160	617	161	177	181
841	185	742	125	326	149
011	170	876	134	480	154
211	200	012	136		
770*					
946	176				
089	143				
234	145				
431	197				
601	171				
805	204				
009	204				
237*					
404	167				
594	190				
775	181				
962	187				
139	177				
<hr/>					
Σt	5501		3290		3017
$\frac{\Sigma t}{N}$	31		21		20
\bar{t}	177.452		156.667		150.850

*Cycle time not included because of fumble or irregularly occurring element.

ANNUAL REPORT OF THE COMMISSIONER OF THE LAND OFFICE
FOR THE YEAR 1900

Total Area		Total Area		Total Area	
Acres	Sq. Miles	Acres	Sq. Miles	Acres	Sq. Miles
100	1.36	100	1.36	100	1.36
200	2.72	200	2.72	200	2.72
300	4.08	300	4.08	300	4.08
400	5.44	400	5.44	400	5.44
500	6.80	500	6.80	500	6.80
600	8.16	600	8.16	600	8.16
700	9.52	700	9.52	700	9.52
800	10.88	800	10.88	800	10.88
900	12.24	900	12.24	900	12.24
1000	13.60	1000	13.60	1000	13.60
1100	14.96	1100	14.96	1100	14.96
1200	16.32	1200	16.32	1200	16.32
1300	17.68	1300	17.68	1300	17.68
1400	19.04	1400	19.04	1400	19.04
1500	20.40	1500	20.40	1500	20.40
1600	21.76	1600	21.76	1600	21.76
1700	23.12	1700	23.12	1700	23.12
1800	24.48	1800	24.48	1800	24.48
1900	25.84	1900	25.84	1900	25.84
2000	27.20	2000	27.20	2000	27.20
2100	28.56	2100	28.56	2100	28.56
2200	29.92	2200	29.92	2200	29.92
2300	31.28	2300	31.28	2300	31.28
2400	32.64	2400	32.64	2400	32.64
2500	34.00	2500	34.00	2500	34.00
2600	35.36	2600	35.36	2600	35.36
2700	36.72	2700	36.72	2700	36.72
2800	38.08	2800	38.08	2800	38.08
2900	39.44	2900	39.44	2900	39.44
3000	40.80	3000	40.80	3000	40.80
3100	42.16	3100	42.16	3100	42.16
3200	43.52	3200	43.52	3200	43.52
3300	44.88	3300	44.88	3300	44.88
3400	46.24	3400	46.24	3400	46.24
3500	47.60	3500	47.60	3500	47.60
3600	48.96	3600	48.96	3600	48.96
3700	50.32	3700	50.32	3700	50.32
3800	51.68	3800	51.68	3800	51.68
3900	53.04	3900	53.04	3900	53.04
4000	54.40	4000	54.40	4000	54.40
4100	55.76	4100	55.76	4100	55.76
4200	57.12	4200	57.12	4200	57.12
4300	58.48	4300	58.48	4300	58.48
4400	59.84	4400	59.84	4400	59.84
4500	61.20	4500	61.20	4500	61.20
4600	62.56	4600	62.56	4600	62.56
4700	63.92	4700	63.92	4700	63.92
4800	65.28	4800	65.28	4800	65.28
4900	66.64	4900	66.64	4900	66.64
5000	68.00	5000	68.00	5000	68.00
5100	69.36	5100	69.36	5100	69.36
5200	70.72	5200	70.72	5200	70.72
5300	72.08	5300	72.08	5300	72.08
5400	73.44	5400	73.44	5400	73.44
5500	74.80	5500	74.80	5500	74.80
5600	76.16	5600	76.16	5600	76.16
5700	77.52	5700	77.52	5700	77.52
5800	78.88	5800	78.88	5800	78.88
5900	80.24	5900	80.24	5900	80.24
6000	81.60	6000	81.60	6000	81.60
6100	82.96	6100	82.96	6100	82.96
6200	84.32	6200	84.32	6200	84.32
6300	85.68	6300	85.68	6300	85.68
6400	87.04	6400	87.04	6400	87.04
6500	88.40	6500	88.40	6500	88.40
6600	89.76	6600	89.76	6600	89.76
6700	91.12	6700	91.12	6700	91.12
6800	92.48	6800	92.48	6800	92.48
6900	93.84	6900	93.84	6900	93.84
7000	95.20	7000	95.20	7000	95.20
7100	96.56	7100	96.56	7100	96.56
7200	97.92	7200	97.92	7200	97.92
7300	99.28	7300	99.28	7300	99.28
7400	100.64	7400	100.64	7400	100.64
7500	102.00	7500	102.00	7500	102.00
7600	103.36	7600	103.36	7600	103.36
7700	104.72	7700	104.72	7700	104.72
7800	106.08	7800	106.08	7800	106.08
7900	107.44	7900	107.44	7900	107.44
8000	108.80	8000	108.80	8000	108.80
8100	110.16	8100	110.16	8100	110.16
8200	111.52	8200	111.52	8200	111.52
8300	112.88	8300	112.88	8300	112.88
8400	114.24	8400	114.24	8400	114.24
8500	115.60	8500	115.60	8500	115.60
8600	116.96	8600	116.96	8600	116.96
8700	118.32	8700	118.32	8700	118.32
8800	119.68	8800	119.68	8800	119.68
8900	121.04	8900	121.04	8900	121.04
9000	122.40	9000	122.40	9000	122.40
9100	123.76	9100	123.76	9100	123.76
9200	125.12	9200	125.12	9200	125.12
9300	126.48	9300	126.48	9300	126.48
9400	127.84	9400	127.84	9400	127.84
9500	129.20	9500	129.20	9500	129.20
9600	130.56	9600	130.56	9600	130.56
9700	131.92	9700	131.92	9700	131.92
9800	133.28	9800	133.28	9800	133.28
9900	134.64	9900	134.64	9900	134.64
10000	136.00	10000	136.00	10000	136.00

Total Area 136.00 Sq. Miles
 Total Area 136.00 Sq. Miles
 Total Area 136.00 Sq. Miles

Other items not included herein are lands in the custody of the State.

Table 11

CALCULATION OF N^1

Operation	Operator		Σt	Σt^2	$N \Sigma t^2$		
1	1	Preferred Hand	865	26921	753788		
		Non-preferred	1205	38459	1461442		
		Bimanually	792	28716	631752		
	2	Preferred Hand	1082	30644	1164472		
		Non-preferred	1046	29916	1106892		
		Bimanually	1133	39391	1299903		
	3	Preferred Hand	1289	43515	1697085		
		Non-preferred	1125	37791	1284894		
		Bimanually	1204	48692	1460760		
2	1	Preferred Hand	1249	38235	1567635		
		Non-preferred	884	28064	785792		
		Bimanually	663	23307	442833		
	2	Preferred Hand	1190	41960	1426640		
		Non-preferred	1216	49486	1484580		
		Bimanually	635	28941	405174		
3	Preferred Hand	1297	49779	1692486			
	Non-preferred	650	26550	424800			
	Bimanually	1540	64586	2389682			
4	Preferred Hand	2888	549615	60457650			
	Non-preferred	888					
	Bimanually	3002	755370	9064440			
5	Preferred Hand	3017	461381	9227620			
	Non-preferred	3290	526104	11048184			
	Bimanually	5501	994191	30819921			
			$(\Sigma t)^2$	$N \Sigma t^2 - (\Sigma t)^2$	N	N^1	
1	1	Preferred Hand	748225	5563	28	11.9	
		Non-preferred	1452025	9417	38	10.4	
		Bimanually	627264	4488	22	11.4	
	2	Preferred Hand	1149184	15288	38	20.9	
		Non-preferred	1094116	12776	37	18.7	
		Bimanually	1283689	16214	33	20.25	
	3	Preferred Hand	1661521	35564	39	34.3	
		Non-preferred	1265625	19269	34	24.3	
		Bimanually	1449616	11144	30	12.3	
2	1	Preferred Hand	1560001	7634	41	7.9	
		Non-preferred	781456	4336	28	10.0	
		Bimanually	439569	3264	19	11.9	
	2	Preferred hand	1416100	10540	34	11.9	
		Non-preferred	1478656	5924	30	6.4	
		Bimanually	403225	1949	14	7.4	
3	Preferred Hand	1682209	10277	34	10.1		
	Non-preferred	422500	2300	16	8.7		
	Bimanually	2371600	18082	37	12.2		

Table 1
Continued

Year	Age	Sex	Location	Group	Notes
1975	10	M	...	...	...
1976	11	F	...	...	...
1977	12	M	...	...	...
1978	13	F	...	...	...
1979	14	M	...	...	...
1980	15	F	...	...	...
1981	16	M	...	...	...
1982	17	F	...	...	...
1983	18	M	...	...	...
1984	19	F	...	...	...
1985	20	M	...	...	...
1986	21	F	...	...	...
1987	22	M	...	...	...
1988	23	F	...	...	...
1989	24	M	...	...	...
1990	25	F	...	...	...
1991	26	M	...	...	...
1992	27	F	...	...	...
1993	28	M	...	...	...
1994	29	F	...	...	...
1995	30	M	...	...	...
1996	31	F	...	...	...
1997	32	M	...	...	...
1998	33	F	...	...	...
1999	34	M	...	...	...
2000	35	F	...	...	...
2001	36	M	...	...	...
2002	37	F	...	...	...
2003	38	M	...	...	...
2004	39	F	...	...	...
2005	40	M	...	...	...
2006	41	F	...	...	...
2007	42	M	...	...	...
2008	43	F	...	...	...
2009	44	M	...	...	...
2010	45	F	...	...	...
2011	46	M	...	...	...
2012	47	F	...	...	...
2013	48	M	...	...	...
2014	49	F	...	...	...
2015	50	M	...	...	...

Table 11 (Continued)

Oper- ation	Oper- ator		$(\sum t)^2$	$\frac{N\sum t^2}{(\sum t)^2}$	N	N^1
4	1	Preferred Hand	6007401	38364	11	10.1
		Non-preferred			4	
		Bimanually	9012004	52436	12	9.3
5	1	Preferred Hand	9102289	125331	20	22
		Non-preferred	1082410	224084	21	33
		Bimanually	30261001	558920	31	29.4

Table 11 (Continued)

Year	Age	Female (%)	Male (%)	Operation	Operation
1977	17	58.88	41.12	1	4
	4				
1978	17	58.26	41.74	1	4
	20	58.51	41.49	1	4
	21	58.80	41.20	1	4
	22				

Table 12

COMPUTATION OF CORRELATION COEFFICIENT
 BETWEEN MEAN CYCLE TIMES FOR PREFERRED HAND OPERATION
 AND PERCENT INCREASE IN CYCLE TIME FOR BIMANUAL OPERATION

Operation	Operator	Cycle Time x	Percent Increase y
1	1	30.893	16.531
	2	28.210	21.705
	3	33.051	21.427
2	1	30.463	14.549
	2	35.000	29.591
3	1	38.147	9.107
4	1	222.818	12.610
5	1	150.850	17.635

Σx 569.432
 Σx^2 78829.607
 $\Sigma x \Sigma y$ 81325.709

Σy 143.155
 Σy^2 2843.741
 Σxy 9127.445

Line of Least Squares.

$$a = \text{slope} = \frac{N \Sigma xy - \Sigma x \Sigma y}{N \Sigma x^2 - (\Sigma x)^2} = -.027$$

$$b = y \text{ intercept} = \frac{\Sigma x^2 \Sigma y - \Sigma x \Sigma xy}{N \Sigma x^2 - (\Sigma x)^2} = 15.972$$

1974-75

OPERATION OF COMMISSION COMPANIES
 BETWEEN 1970 AND 1975 FOR GENERAL OPERATION
 AND FINANCIAL STATEMENTS

Operation Number	Year	Revenue	Expenses	Profit
1	1970	50.000	30.000	20.000
2	1971	50.000	30.000	20.000
3	1972	50.000	30.000	20.000
4	1973	50.000	30.000	20.000
5	1974	50.000	30.000	20.000
6	1975	50.000	30.000	20.000

$\sum x = 300.000$
 $\sum y = 120.000$
 $\sum xy = 60.000.000$
 $\sum x^2 = 900.000$
 $\sum y^2 = 48.000.000$

Line of best fit

$$b = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sum x^2 - \frac{(\sum x)^2}{n}} = \frac{60.000.000 - \frac{300.000 \times 120.000}{6}}{900.000 - \frac{(300.000)^2}{6}} = 12.000$$

$$a = \text{slope} = \frac{\sum y - \frac{\sum x \sum y}{n}}{n} = \frac{120.000 - \frac{300.000 \times 120.000}{6}}{6} = 20.000$$

BIBLIOGRAPHY

1. Barnes, R. M., Mundel, M. E., MacKenzie, J. M.,
"Studies of One and Two-Handed Work"; Studies in
Engineering, University of Iowa, Bulletin 21, 1940.
2. Hoel, P. G., Introduction to Mathematical Statistics;
New York, John Wiley and Sons, 1947.
3. Mundel, M. E., Systematic Motion and Time Study;
New York, Prentice Hall, 1947.
Motion & Time Study Principles and Practice;
New York, Prentice Hall, 1950 (manuscript before
publisher)

BIBLIOGRAPHY

1. Marcus, H. G., Wang, H. G., and Wang, J. S., "Studies of One and Two-Phase Flow", Journal of Engineering University of Iowa, October 1940.
2. Wang, H. G., Introduction to Mathematical Statistics, New York, John Wiley and Sons, 1947.
3. Wang, H. G., Statistical Analysis and Test Theory, New York, Interscience, 1947.
4. Wang, H. G., Statistical Analysis and Test Theory, New York, Interscience, 1947.

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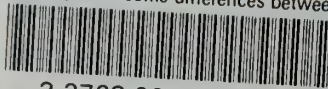
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