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AN EXPERIMENTAL EVALUATION OF THE PRESENCE OF AN ANALYST ON WORK PERFORMANCE TIMES IN TIME STUDY ANALYSIS

A THESIS

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OF AN ANALYST ON WORK PERFORMANCE TIMES IN
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LIST OF SYMBOLS

a	Sub-index for observations during time studies
b	Sub-index for observations before time studies
n	Sample size
M	Mean values
$\bar{X}$	Sample mean
S	Sample variance
H_o	Null hypothesis
H_1	Alternate hypothesis
F	Test statistic for differences in the variances
t	Test statistic for differences in the means when the variances are equal
t'	Test statistic for differences in the means when the variances are not equal
ν	Degrees of freedom for the t' test
α	Per cent level of significance

SUMMARY

An experiment was designed to ascertain the influence of a time study analyst on the workers engaged in an industrial operation. The general purpose of the experiment was to determine if the operator changes significantly his performance while being studied and timed by the analyst.

Three experienced female workers engaged in a typical repetitive assembly operation in a shirt manufacturing company were selected to be observed in performing their jobs over a period of three months. A record of the operation was achieved by means of motion pictures taken of the work place by concealed cameras operated by remote control. Objective data were accumulated prior to the period of time study of the particular workers involved to establish a typical rate of work. Then, this typical rate was compared to the performance data collected when the time study analyst was present to ascertain if, in fact, a significant difference did exist.

The data were analyzed statistically for differences in the means and the variances at the five per cent level of significance. It was found that all three workers observed showed a significant decrease in the performance time when they were being studied by the analyst. Two of the workers showed also a significant increase of uniformity in performing the job when they were being studied by the analyst.

It was concluded that the workers for this particular environment did change significantly their performance while being studied and timed by an analyst.

CHAPTER I

INTRODUCTION

This study presents an experiment comparing two contrasting or different methods of taking performance time of an operator. In method A a typical stop-watch time-study is made with the analyst taking the time in the presence of the workers. In method B the same workers are studied by means of a concealed camera without their awareness.

The general purpose of this experiment is to determine if the operator changes significantly his performance while being studied and timed by the analyst. There has been considerable speculation that a worker who is being time-studied may, and perhaps often does, slow down his work pace during the entire sampling procedure. No objective evidence, however, has come to the attention of this investigator to prove the truth or falsity of this contention. Objective data were accumulated prior to the period of time study on the particular workers involved to establish a typical rate of work. Then this typical rate was compared to the performance data collected when the time-study analyst was present to ascertain if, in fact, a significant difference did exist.

There has been considerable research effort expended to get more consistency in time study methods. These efforts have stressed the refinement of existing techniques, many of which have come down through the years.

In sharp contrast to the techniques improvement movement has been the paucity of studies which have tried to validate the soundness of the principles underlying time studies. For example, if the very presence of a time analyst produces a significant change in the performance of the operator, this effect should be ascertained quantitatively before establishing time standards. It would appear somewhat premature to rush ahead to establish standards, for example, before ascertaining the crucial variables and influences going into the performances of the original times.

It seems safe to assume that Taylor, the originator of time study, and the refinements in methods brought about by the Gilbreths, did not envision today's ultra-refinements of motion-times. These investigators were primarily concerned with the goal of trying to establish a reasonable yardstick for determining what they called a "fair day's work".

The results obtained by the early investigators are plain for all to see. They thought their methods of timing did help to bring about greater work effectiveness, increased production, and reduced cost. These principles and methods were gradually brought together as the techniques for time study.

Because of the growing demand for the application of time study techniques, there was no great concern on the part of the time study analysts to question or to investigate the basic assumptions underlying the methods. These men were more or less satisfied with the fact that the techniques worked reasonably well.

The appearance of the so-called "efficiency experts" did much to spread the use of the techniques. Their enthusiastically exaggerated claims and questionable methods did much to confuse the field and to make the techniques suspect.

The natural conservatism of the worker and his characteristic mistrust for that which is strange to him has often caused him to resist time study. He has rebelled to a certain extent, also, over the manner in which time study has been applied and misapplied. The present era has seen industrial engineering move firmly towards validating its basic assumptions. This step has been hastened by numerous factors. An important one is the concern of the social sciences; namely, psychology and sociology, with their focus on the individual worker and his attitudes, feelings, and general motivation to perform on the job. In addition to the social scientist has also come the influence of the physiologist and the physician, and their concern with worker effort, fatigue, strain, etc.

These related sciences have raised serious questions concerning the validity of a method or a technique merely because it appears to work reasonably well. They have raised serious questions concerning the rationale behind time study. Some of the questions are:

How do you know what a "normal" pace is for a worker?

Is the assumption of a normal pace sound?

What influence does the timer himself have on the performance of the worker who is being timed?

Does the analyst assume zero influence of his presence on the worker being timed? If not, how sound is the criterion for setting levels?

It would seem reasonable to conclude that most time study analysts realize that they may, by their very presence in timing a worker, be influencing his performance in some manner. Therefore, it follows that research should be directed towards ascertaining what, if any, influence is being exerted. It is to this general area that this study now addresses itself.

This study advances the null hypothesis that times for job performance in the presence of a time study analyst and registered by a concealed camera do not differ significantly from those taken by the concealed camera when the time study analyst is not present.

CHAPTER II

REVIEW OF THE LITERATURE

The movement towards "Scientific Management" which first introduced time-study (1) (2) was first initiated with the publication of a paper entitled "A Differential Piece Rate" by Frederick W. Taylor in 1895 (3) (4).

This first and the subsequent publications of Taylor spelled out not only a procedure, but a philosophy of the relationship between labor and management. Ever since this publication, a series of controversies have accompanied the development of principles and methods concerning the evaluation of work.

In his writings, F. W. Taylor more than once served warning that the mechanism of management must not be mistaken for its essence or underlying philosophies. While it is often misleading to lift brief sentences from their context, these two statements are both so clear and so conclusive, that they need little elaboration (5). No doubt it is in the nature of things that we should have disregarded Taylor's warning in our eagerness to systematize our growing knowledge, and in our hurry to reduce it to tabloid form for the consumption and the use of the technician. Nevertheless, such urgency has sometimes led us away from first principles and, as Taylor feared, has led us to exalt technique above philosophy (6). However, although Taylor does point out most of the limitations to which the field is subject, because of the inadequate knowledge of the complex relationships involved, his writings clearly denounce the acceptance of a purely mechanical view of the role of the worker in industry. Gomberg (7) commenting on a paper presented by Taylor, entitled "The Present State of the Art of Scientific Management" (8) says,

> Here the substance, the mechanical concepts with which science had been made to work in the field of nineteen century physics, was artificially transplanted into the field of time-study techniques. The fact that the only claim that could be made for these assumptions was that they were subject to tests of validity by the scientific method was confused with the superficial resemblance between the directions to divide a man's work into simple elementary motions and the appearance of the atomic and molecular theory of physical science.

On the other hand, Taylor used the expression "time study" somewhat loosely, to embrace both "time study" and "motion study" as we understand them today (9). It took the Gilbreths to identify and define motion as a separate, though complementary component of the work pattern. "Motion study is essentially qualitative while time study is quantitative"..."The object of motion study is to improve and standardize conditions of work, and that of time study is to serve as a basis for the measurement of work" (10). Frank Gilbreth emphasizes the importance of motion study and writes:

> There is no waste of any kind in the world that equals the waste from needless, ill directed, and ineffective motions. When one realizes that in such a trade as bricklaying alone, the motions now adopted after careful study have already cut down the bricklayer's work more than 2/3, it is possible to realize the amount of energy that is wasted by the workers of this country (11).
>
> .....Our duty is to study the motions and to reduce them as rapidly as possible to standard sets of least in number, least in fatigue, yet most effective motions (12).

Lillian Gilbreth in an article on "Work and Leisure" (13) says:

> An engineer is a person who believes in measurement, who knows how to measure, does measure, and is willing to abide by the results of his measurements, whether they suit his pre-conceived notions or not.

According to this line of thinking, micromotion was a logical step forward in the refinement of motion and time study techniques; and further refinement of measurement was seen as the logical trend in the field as it happened. However, measurements were limited to the physical, and particularly the mechanical aspects of the subject. The refinement of techniques brought along the development of different methods of rating, and the use of the so-called allowances.

The many methods of arriving at standard times from recorded times divide roughly into three main groups (14):

1. Application of mathematical formulas;
2. Application of external correction factors derived from "leveling", "rating", "element selection", etc.;
3. Comparison of specific motion times with pre-determined standards.

The first of these is now outmoded, "having been the result of early overenthusiasm for the use of science in management" (15). A common requirement in time-study is that the standard time represents the performance of a man of average skill applying average effort under normal conditions (16) (17). This would logically restrict the operators selected for time studies, to the average skill working with average effort. In practice, however, time studies do not involve operators selected with reference to distribution of workers with respect to such variables. Instead, operators are chosen on the basis of intelligence, co-operation, good will -- or even because they are superior operators --

and adjustments are made of observed elemental times in arriving at a standard time supposedly representative of the performance of an average man (18) (19). This involves the process of rating defined by the National Committee on Effort Rating of the Society for Advancement of Management as "the process during which a time study engineer compares the performance of the operator under observation with the observer's own concept of normal" (20).

Abruzzi and Littauer (21) report wide differences among the methods used for adjusting the observed time to arrive at a standard appropriate to the average or normal employee. A leveling procedure advocated by Lowry, Maynard and Stegemerten, under which average time taken to complete task elements subject to control by the operator is multiplied by a leveling factor derived from ratings on skill, effort, consistency and conditions (22). In still another application of ratings, only ratings of effort are used in the adjustment or leveling of the time study data (23), while Mundel proposes that ratings on two factors, namely pace and job difficulty, be used in the adjustment of the elapsed time (24) (25).

In addition to the application of ratings in setting standard times, further adjustments are generally made in the form of allowances to provide for personal needs, for delays over which the worker has no control, to prevent undue fatigue and the like (26). As in the case of rating factors, there are variations among time-study engineers with respect to the type of allowance and to the time allowed. A survey of time-study literature by Mundel (27), in 1950, shows a range of "personal allowances" from a maximum of four per cent under one system, to a maximum of fifty per cent under another. Barnes proposes for light work, on 8-hour daily shifts, two to five per cent (ten to twenty-four minutes) (28). Data from studies of work decrement during various parts of the day -- particularly at the end of the work shift -- have been used as the basis in deciding of the size of the fatigue allowance. Mundel, however, points out that as the heavy work in factories gradually decreases, because of the greater use of machinery and power equipment, "the fatigue allowance becomes one of decreasing importance to the time-study analyst" (29).

From the viewpoint of a scientific approach, arriving at allowances for fatigue constitutes a problem of particular complexity, since studies by psychologists and physiologists have produced little in the way of usable techniques (other than output itself) for measuring fatigue. Hall asserts that

> Engineers cannot adequately evaluate the functional characteristics of a machine on the exclusive basis of utilizing a stop-watch and making a time study. It is equally impossible to adequately evaluate the functional capacity of the human machine by the same methods, since the stop-watch is inherently unable to measure the physiological cost of a job (30).

Again, the purely pragmatic approach established by the pioneer workers in the field of time study, closely followed by their successors, leaves an open way for questioning the validity of the procedures employed in arriving at time standards. The inherent range of individual differences raises the psychological factors which have been largely overlooked in the application of rating factors. Presgrave points out that "engineers are already aware of the importance of such facts and of the needs for determining the limits of adjustment by means of appropriate research" (31). However, in the actual industrial situation, "Practicioners have done virtually nothing to justify time-study from scientific, sociological or psychological grounds, having been content to rest their case on the one proved fact that through their techniques they have been 'pre-eminently successful in increasing output and decreasing costs'" (32).

On the other hand, Gillespie (33) questions the soundness of motion study in writing about "Work Psychodynamics":

> One peculiar aspect of motion study in its wide sense of being the spearhead of industrial planning methods is that the study of human beings has not being related to the work function as a whole; to the economic function, yes; but to the psychological work function, no. Motion study undoubtedly reduces operator free expression and reduces operator interest flow, a fact which will be obvious to anyone who compares studied motion with handicraft and craft work. Yet, as we shall see, Jung and Freud insist that work is of prime importance for real living in a civilized community; but, they say, work must be freely done. If this were true, and I think it is true, we should either drop motion study as preached or, if we accept the economic necessity for it, we must also accept the psychological and social necessity for free expressions in the work situation.

Gillespie also raises the question as to whether minute, elemental times -- no matter how accurate -- can justifiably be added to provide a time-representation of the "job" as a whole, and cites in his support the opinion of Professor Freeman of Cornell University:

> The student will do well to keep in mind that total behavior is a produce of interactions of parts, but that experimentally isolated part processes do not constitute the elements out of which whole processes are concatenated. Behavior is always unitary (34).

Furthermore, procedures used by some methods engineers involve no direct timing of the different elements of the job, but depend on setting standards upon a so-called "law of motion", such as Segur's, which states, without adequate substantiation (35) that "within practical limits the time required by all expert workers to perform true fundamental motions are constant" (36).

At this point, one more variable enters the already complex and inconsistent structure of time study considered in its full dimensions; the reliability of the instruments used in the timing of the operations. Considerable attention has been directed to such questions as to whether "continuous" or "snap-back" operation of the stop-watch yields more reliable and more accurate measurements. Mundel recommends an approach based on a statistical criterion for decisions as to the number of readings. According to this, he sets a five per cent level of significance for obtaining the true average for the element for the pace at which it was performed (37). However, research made by Richard B. Leng and cited by Morrow (38), suggests that practical difficulties may exist in complying with such criterion, since it was shown that from 14 to 75 observations, with an average of 28, were required to obtain a reliable reading to the nearest .01 minute. Leng also reports on the number of observations necessary to obtain reliable readings to the nearest hundredth of a minute; for the Marstochron 4, and for the wink-counter 9. Leng suggests that the Marstochron be used on short elements, all less than .05 minutes, the stop-watch, using sufficient readings be used if all elements are over .05 minutes, and the wink-counter be used in many borderline cases, for elements of .03 or longer (39).

An analysis of time study methods and findings leads Presgrave to the assumption that the average element observed in time study is .01 minutes duration (40). An error of .01 minutes thus represents an error of ten per cent in the measurement of the average elemental time. According to Gomberg (41) "no time study technique can end all disputes between management and labor. All that it can do is provide a frame of reference with which the dispute can be examined". He adds

> Obviously, if after months of negotiations and possible strikes at great financial sacrifice to both sides, a settlement has been reached involving a ten per cent change in the basic rates, neither management nor labor is prepared to sacrifice its respective rights to the blind operation of a technique of questionable accuracy (42).

The question then arises as to whether even by using the most refined techniques available, dealing with the average skilled worker doing the average effort, the sole presence of the "efficiency expert" when rating the operation, causes an error as great or greater than the ten per cent limits assumed for the average element. The possible influence of an "efficiency expert" is made clear in the following quotation from Gillespie:

> When the motion observer is at work, there is more than a physical situation in which there is an organism called an observer and another quite separate organism called an operator (43).

He goes on to say:

> It is people and events we are facing and, whether we like it or not, the attainment of the purpose of the motion observer is dependent on factors which cannot be treated as events. The total situation includes the motion observer with his purposes, his attitudes, his appearances, and his mode of dress and address, and the operator with his purposes, his attitude, his appearance, and his mode of address and dress (44).

Gomberg (45) comments on Hersey's findings as follows:

> .....Other emotional factors have an unpredictable influence on the motivator drive, among them the emotional cycle. Hersey found as the result of a study of twelve men for a year, that there was a definite periodicity to their emotional tonus. It could not be accounted for by environmental happenings, climatic changes, or physical conditions, but it definitely affected the feeling of effort and performance on the job (46).

In the development of a time study, Professor Myers (47) identifies three main classes of variations influencing the quality performance and production rate of workers: the mechanical, the physiological and the psychological. Gomberg (48) adds a fourth, the sociological, and further says:

> It is at once apparent that these variables are not independent, but are mutually dependent. Sociological factors like the quality of the relationship between the workers and the management have their psychological effects. The psychological forces in turn have their physiological effects, as, for example, when emotional excitement is followed by a nervous stomach. In turn, physiological considerations such as poor nutrition affect the mental health of the working group. Effects and cross effects can be multiplied endlessly and should give some idea of the complexity of the mathematical relationships that would have to be conceived by the Laplacian universal mind (49).

As for the presence of the time-study man, again, could we in the light of these considerations disregard the effects and cross effects automatically induced on the worker, and therefore on the results to be obtained from the time studies? And, again, is the per cent error assumed for the average element made inconsequential by the error introduced by this consideration?

The literature does not report a quantitative evaluation of such problem. The experiment discussed in the following chapters has been therefore designed in an effort to provide an answer to the above questions.

CHAPTER III

EXPERIMENTAL DESIGN

In complying with the purpose of this study, an experimental environment was designed to study the extent to which the presence of the time study analyst affects the outcome of a time study.

In designing an experiment of this nature, many variables come into consideration, which may affect the outcome. In reviewing the literature, we cited four main classes of variations influencing the quality performance and production rate of workers; namely, the mechanical, the sociological, the physiological and the psychological. As discussed then, no one of these variables can be considered independent, and on the contrary, there exists a complex interrelationship. The experiment should, then, be restricted to the evaluation of the total effect that results from the conjugation of these variables, without any attempt to identify them separately. However, if a certain degree of homogeneity is attained, namely, by selecting workers of approximately the same social level, the same economic scale, the same sex, age and experience, the same background, qualifications and emotional stability, any significant variation in their performances -- under study and not under study -- would necessarily reflect the effect introduced by the presence of the time study analyst, regardless of the complexity of the factors creating such effect.

With this in mind, each one of the factors was minimized in its variability, to the maximum extent possible under the conditions of the experiment. In the first place, the sociological factors were accounted for in two different ways:

1. By selecting an industry located in a suburban area, where the labor comes mainly from the vicinity.

2. By selecting an operation performed by female workers in the range of 30 to 50 years of age, most of them married and with children, working to help support their families.

Considerations such as the internal social environment predominant among the workers engaged in the operation under study, or "working levels" as suggested by the Hawthorne studies (50), are beyond the scope of this study. However, a wage plan based on piece rates and incentives for time saved, successfully run in the plant under study, plus a long record of fairly good industrial relations, seem to provide at least a reasonable ground for assuming social stability within the company.

Mechanical factors such as the condition of equipment and tools were accounted for by checking with the engineering department of the company over the mechanical condition of the machines and also by selecting for study only an operation where all the workers use the same type of machine. On the other hand, the inspection system set up by the company insures availability of raw material at all times, and continuity of flow.

Other considerations as illumination and ventilation systems were deemed adequate, according to the standards used in that industry. The noise level, though not measured, is not considered to be over 25 SIL (51). Temperature and relative humidity are maintained at the normal levels through an air-conditioning system in the plant.

Physiological factors as fatigue were considered in the sense that the operators were observed on the same job, under the same conditions, and therefore it would normally be expected that under the same physiological tax they would respond to the same stimuli. Vision was considered an important factor. Furthermore, the operators selected were reported all in good physical condition.

The psychological implications in the experiment may be considered of three classes:

1. Those concerned with aptitudes such as manual dexterity, reaction time and the like.

To account for this, the operators were selected on the grounds of experience (Training time: 26 weeks as established by company policies, plus over three years' experience) to discard variability introduced by "learning on the job", and stability of production as indicated by the records of the company.

2. Those concerned with emotional stability and temper. Although no medical reports were available on the emotional stability of the workers selected, they were regarded as emotionally stable persons by their supervisors. Furthermore, the absenteeism level was considered normal.

It was fully realized that, as discussed in the review of the literature, some emotional factors have an unpredictable influence on the motivator drive, among them the emotional cycle. A period of three months (winter season) over which the studies were conducted is not likely to reflect this factor, though it may give an indication of the operator's feelings of effort and performance on the job and its consequent effect on the output.

3. Those concerned with the motivation of the workers. Although motivation is a complex factor, in general, the record of the workers selected on the same job gives an indication of "the liking of the job". On the other hand, the operation selected was run under the same incentive plan, the same wage scale, and the same environmental conditions prevailed. A man-paced operation was selected.

4. Feelings of the workers for or against the analyst.

To account for this, the time studies were performed by two engineers of the company, not especially liked or disliked by the workers.

The main factors introducing variations having been considered and accounted for, a comparison between the performances of an operator when under study by an analyst, and when not under study by an analyst, should give us data as to the effect caused in the man-machine system by the introduction of the time study analyst on the workplace.

In order to carry out the experiment a procedure should be devised to gather the observations accurately and precisely, without introducing further variations due to the recording system. These called for an observation of the worker without her awareness. Although this type of observation, if known to the workers, is likely to produce a negative attitude on their part, it was considered inherent to the experiment.

Accordingly, movie cameras were installed in a way invisible to the worker, directly in front of the workplace (See Fig. 2). In this way, the operator was at no time aware that she was observed and her performance could be recorded at any time by simply turning the camera on by remote control from a place out of her control. However, should the operator known of the presence of the cameras, which was very improbable, she still would not be able to know when the camera was gathering information or whether the camera was focused on her.

It is worth noticing at this time that this particular set-up was made possible through the co-operation of both top management and the union. The latter was consulted to insure co-operation and avoid possible detriment of the normally good industrial relations situation in the company. However, the union did not know either in what department or in what particular operation the studies were to be conducted.

The type of equipment used and the pertinent details of its installation will be the subject of the following chapter.

CHAPTER IV

EQUIPMENT SELECTION AND INSTALLATION

Two time-lapse memomotion cameras, type Keystone Criterion, 16 mm, Model A-9, were used in the experiment. The cameras had been modified by the addition of a synchronous motor of the following characteristics:

Volts:	115 AC
Watts input:	7.5
R. P. M.	25
Torque:	12 in. oz.
Capacitor:	.85 MFD
Duty:	continuous

These motors enabled the cameras to take memomotion pictures at the rate of 25 frames per minute, and the exposure of each frame was set at 1/30 second. The lenses were rated at f3.5.

A Kodak Tri-X reversal movie film was used since the brightness measured 5 in Weston units. The cameras were mounted on tripods and set on position at approximately three feet above the elevated platform on which they were standing. The cameras were placed inside an elevated tunnel, designed as a part of a ventilation system, which divides the Assembly Room into two large symmetrical sections (See Fig. 2). In the section on which the cameras were located, the dimensions of the tunnel are 5 by 5 ft. The lenses of the cameras were focused onto the workplace through visual fields provided by the holes of net-shaped windows 12 by

30 inches, located on each of the lateral sides of the rectangular-shaped tunnel. The size of the holes in front of which the camera was located, the distance of the camera from the net-shaped windows (approximately eight inches) and the contrast between the dark inside of the tunnel and the intense illumination of the room, kept the cameras from being noticed by the workers. As an additional precaution, the front of the cameras, with the exception of the lenses, was covered with black tape.

The netted windows were distributed symmetrically over the side-walls of the tunnel, five feet apart. This distribution allowed for the observation of two workers with the same camera (See Fig. 2). The bottom side of the tunnel was approximately 10 feet above the floor. Thus, the point of observation was located over the upper vertex of a triangle 13 feet high and nine feet wide.

Figure 1 shows one of the workers observed in performing the job. It also shows the disposition of the workplace. The picture was obtained from a sample of memomotion film.

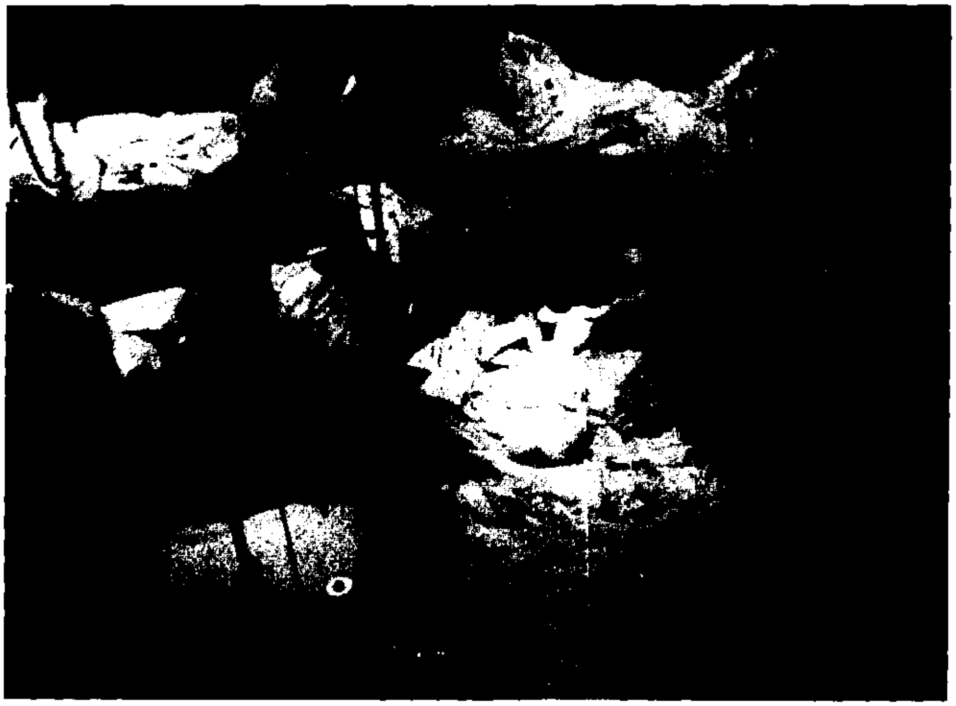
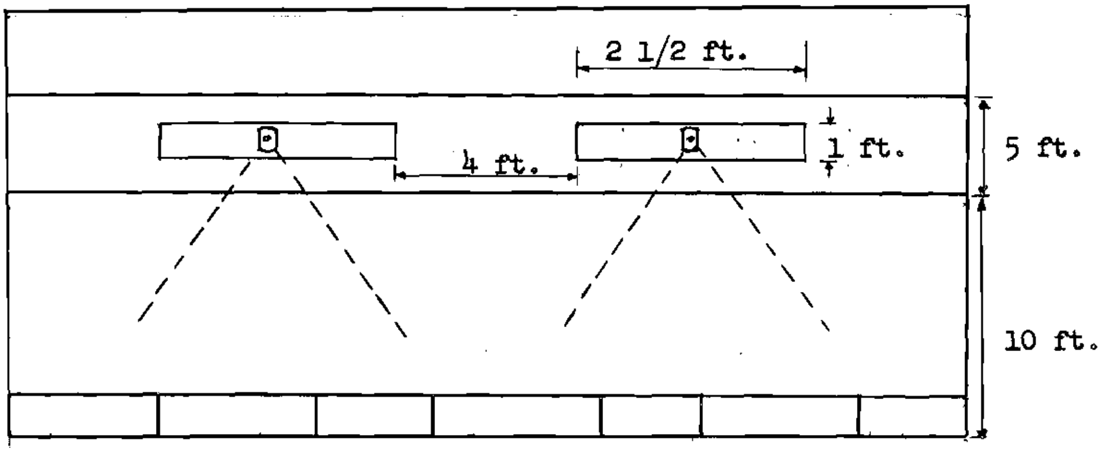
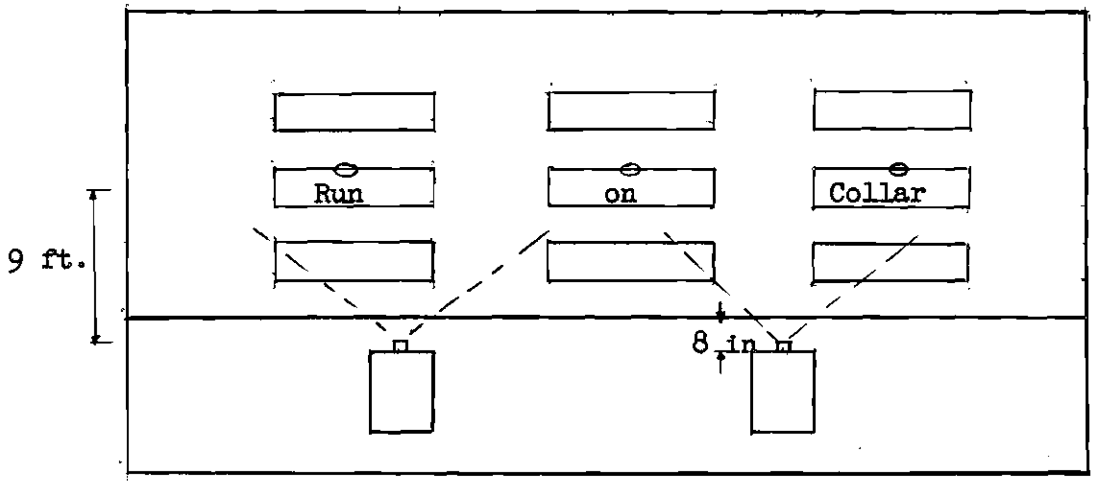


Fig. 1 The Workplace. Sample of Memomotion Film.



Elevation



Plan

Fig. 2 Camera and Workplace Layout
Elevation and Plan

CHAPTER V

EXPERIMENTAL PROCEDURE

Three experienced female workers engaged in a typical repetitive assembly operation called "Run on Collar" in a shirt manufacturing company located in the southwest section of Atlanta, were selected to be observed in performing their jobs over a period of three months.

A record of the operation was achieved by means of motion pictures taken of the workplace by cameras assembled with synchronous motors operated by remote control. Records of the operation were taken in the following fashion:

1. Within two weeks before time studies were taken;
2. Within 45 minutes before time studies were taken;
3. While time studies were taken;
4. Within 45 minutes after time studies were taken;
5. Within two weeks after time studies were taken.

Figure 3 shows the schedules set for observations on the workers selected. Five workers were studied, but only three met the experimental requirements.

The operation selected consists of four repetitive elements, namely:

1. Pick up, position shirt and collar to needle,
2. Backstitch and stitch approximately to center,
3. Stitch to within 1 1/2 inch of end of collar,
4. Align band end and complete stitching and backstitch,

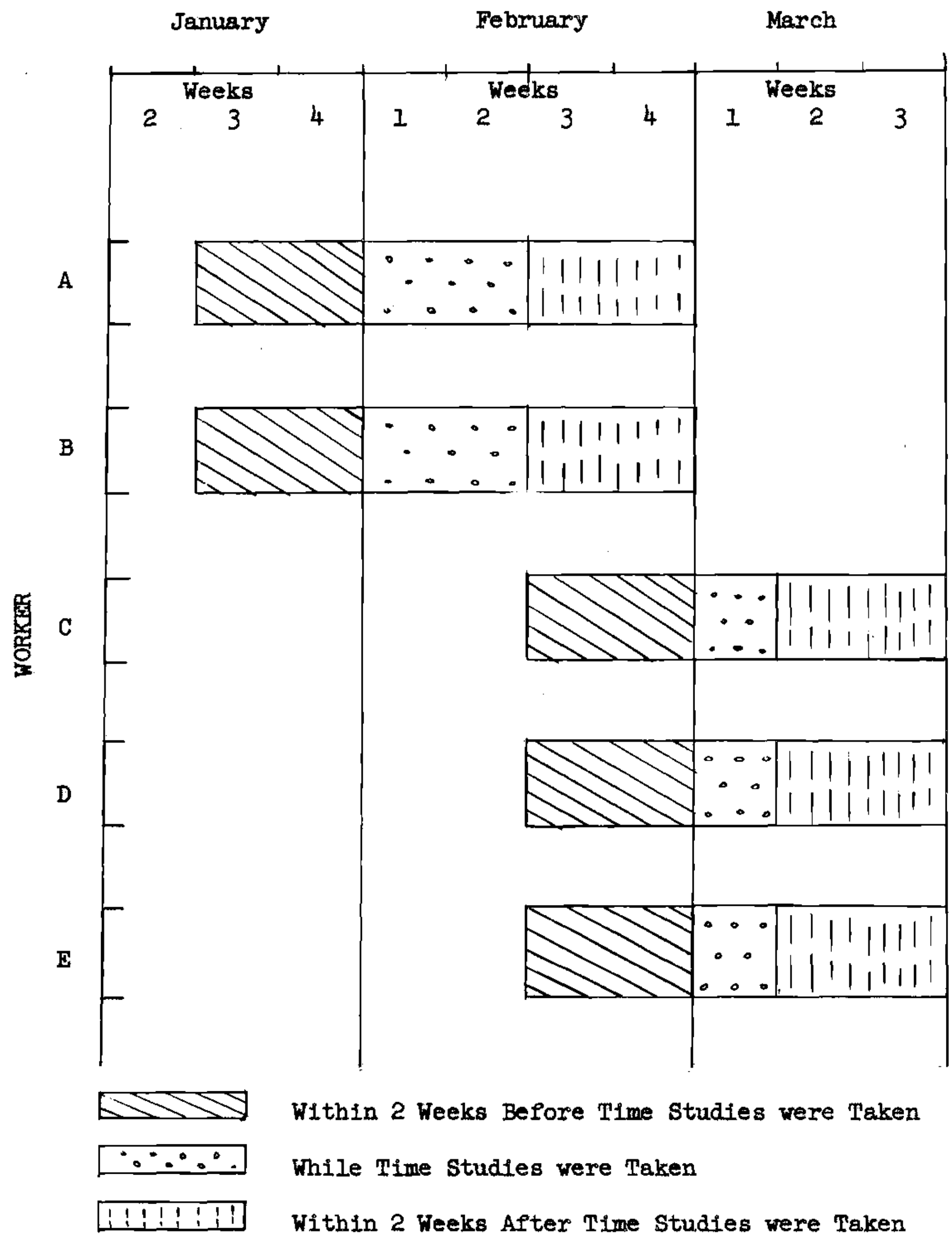


Fig. 3 Schedule for Observations of the Workers Originally Selected

and six non-repetitive or occasional elements, as follows:

1. Chip and mark coupon,
2. Get parts and lay on machine bed,
3. Position two dozen shirts in lap,
4. Position collars under machine arch and check,
5. Thread needle,
6. Repairs.

The following is a detailed account of the job performed by the operator:

1. Slide chair back, reach into "Second Join chute", pick up bundle of shirt parts (collars, cuffs, sleeves), place on machine table. Slide hand under "Second Joined shirts", drape across lap with backs to operators right and fronts to her left cheek to see that no part of shirt is touching floor.

a. If no work is available in "Second Join chute", it is provided to operator by service person.

2. Remove collars from bundle of parts, count (if bundle of collars is found to be short, call service girl for fill in; if as many as three short and no fill in collars are available, service girl removes bundle from operator). Check collar stamp and style against stamp on left front of shirt. If either are in error, call supervisor. Clip and keep pay coupon, write repair number on control ticket, replace under string on bundle of parts in cuffs and sleeves. Place collars under arm of machine stamp side down.

3. Pick up shirt, place on machine table holding right front at underface edge; with right hand select top collar from stack, place bot-

tom end of collar against edge of underface stitch, holding the collar and shirt together place to needle at band end, cut edges against gauge. Back-stitch securely beginning of seam continue stitching using right hand to hold collar and left to guide shirt. The quartermark on bottom sew end of collar matches join seam of right front. Work is held evenly against gauge, leaving no gathers across label or around front. Back-stitch end of seam on button hole end of collar. Measure at least two collars out of each bundle for collar quartering.

Appendices I, II and III include an account of the operator's characteristics and background, a summary of the standards actually set on the elements of the operation and a flow chart of the process of making the shirt.

The data for each operator was recorded in three 100 ft. films. At forty 16 mm frames per foot, 100 feet of film is equivalent to 4000 frames. At the rate of 25 frames per minute information could be recorded over a period of 160 minutes, without re-loading the camera. The information corresponding to the records of the operation mentioned on page 23 was gathered as follows: Numeral 1 was covered in one file spread over the time allowed at times preferable in the middle hours of the morning and on random days. Numerals 2, 3, and 4 were covered in one film run continuously on the time immediately before, while and immediately after the time studies were taken. Numeral 5 was covered in one film under the same conditions of Numeral 1.

The data so obtained was analyzed statistically at the five per cent level of significance for verification in the worker's performances according to the procedure outlined in the following chapter.

CHAPTER VI

ANALYSIS OF DATA

The data were recorded by means of a systematic inspection of the films. The film analysis was made with a Bell & Howell Motion and Time Study Projector, model XD, Design No. 57, equipped with a frame counter and heat filter. The beginning and end of each set of observations were identified and recorded in terms of frame numbers.

Since the films were taken at a speed of 25 frames per minute, each frame is then equivalent to 1/25 minute or four-hundredths of a minute. The accuracy in the readings allowed by the frame counter is $\pm$ 1/4 frame. This means that a maximum error of 0.25 per cent might be induced, if the positive and negative values failed to compensate each other. However, if an analysis of each of the elements making up the cycle were to be made, an experimental error of up to one per cent could possibly result, since each complete cycle is made up of four basic elements. This consideration led us to analyze the data by complete cycles rather than by the separate elements making up the cycle.

Tables 1 a through 3 c show a tabulation of the results obtained for each complete cycle. The particular set-up of the experiment did not allow for the attainment of a uniform sample size in every case or for the comparison of the workers during all of the five periods set forth at the beginning of Chapter V. These changes came about because of a number of reasons. For the period corresponding to two weeks before time studies were taken, the information was recorded in one film (for each worker) capable of storing up to 220 cycles. The time studies were taken for samples of only approximately 100 cycles, due to the limited availability of the engineer's time assigned by the company for the study; namely, one hour per worker. Since information corresponding to the period immediately before and immediately after the time studies were taken necessarily had to be recorded in the same film in which the time studies were recorded, the samples for these periods were restricted to a maximum of 120 cycles.

A discussion of the results for the period corresponding to two weeks after the time studies were taken is omitted, due to the failure of the engineers to take time studies of the workers involved on the times scheduled.

The data were tabulated and plotted in histograms (See Fig. 5 a through 9 b). The shape of the distributions shown in the histograms suggested that a test for normality was necessary (See Fig. 11 through 15 and Tables 4 a through 6 b) before attempting any test for significant differences in the variances or in the means. Whenever the shape of the distribution deviated considerably from normal, as indicated by the appearance of a curve on the probability paper used for the test (52), the data were transformed to a normal distribution by means of an arc sine transformation (53) (See Fig. 10).

Once the distribution was demonstrated to be approximately normal by the appearance of a straight line, as in Fig. 11 through 16 and Fig. 17, an F test for equality of variances was made. Depending on the result of the F test, a <u>t</u> or a <u>t'</u> test (54) was carried out for testing the significance of observed differences in the means (See Fig. 17 through

19). A level of significance of five per cent was selected for these significant tests.

Figures 5 a, 5 b and 8 a, give an idea of the results obtained for worker A. The distributions obtained for data corresponding to the periods within two weeks before time studies were taken and while time studies were taken appeared to be approximately normal, as indicated by the appearance of straight lines in Fig. 11 and 16 (See Fig. 11 and 12 and Tables 4 a and 4 b for worker A). No differences in the variances for the above data were revealed by the F test at the five per cent level. However, a significant difference in the means was obtained by the use of the t test (See Fig. 22). An examination of the value of the mean time for the period immediately before time studies were taken indicates a close proximity to the corresponding mean time for work done during the time studies (See Fig. 5 a, 8 b and 6 a, 8 a). The memomotion film revealed that both worker B and worker A were included in one series of time samples in which worker B was under study by the analyst. A comparison between Fig. 5 a and 8 b with Fig. 5 b shows that worker A was performing at a more uniform and accelerated pace immediately before and while time studies were taken. These data may be interpreted as an indication of the influence of the time study analyst on the performance of the workers, regardless of whether they were under direct study. These experienced workers performed at a more uniform and accelerated pace while the time study engineer was present.

Data on worker A show a similar trend to that obtained for workers B and C (see corresponding figures and tables). A comparison between Fig. 6 a and 9 a and 7 b and 9 b shows that the performance of the workers while time studies are taken and immediately after time studies are taken are very similar. The F tests for worker C and A revealed significant differences in the variances for observations taken within two weeks before time studies were begun, in contrast to those taken during time study. This tendency is observed in worker B, though not to the extent of being detected by the F test at the five per cent level (See Fig. 5 a, 5 b, 8 b and 17 for worker A; Fig. 6 a, 6 b, 8 b and 18 for worker B; and Fig. 7 a, 7 b and 19 for worker C).

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

The null hypothesis that the times for job performance taken by a time study analyst and registered by a concealed camera do not differ significantly from those taken by the concealed camera when the time study analyst is not present must, on the basis of these data, be rejected. These three experienced workers performed more uniformly and rapidly when being timed by the analyst than when sample times were taken in the absence of the analyst.

The difference between the means of the total cycle time for the methods of analyst present versus analyst absent (both recorded by the concealed camera) was significant at the five per cent level of significance. This difference was based on camera times obtained when the analyst was taking one-hour observations or 100 cycle times versus camera times of up to 220 cycles obtained when time study analyst was absent.

A number of possible variables may account for the greater uniformity and for the increase in speed when being timed by the analyst. Some of these are:

1. These were experienced workers who may have felt they had nothing to fear from the results of time studies taken by the analyst and therefore speeded up their performances.

2. Change may have resulted from the desire of the workers being observed to perform at their very best.

3. There may have been sufficient variations in the times of day during which sampling occurred to produce the changes observed.

4. The changes observed here may be specific to this type of industry and the kinds of workers it selects.

At best, these conclusions can be taken only as tentative. Limitations of time, number of jobs studied, number of workers observed and number of companies involved, keep us from generalizing. Definite conclusions are necessarily restricted by sociological considerations inside and outside the company under study.

The following recommendations, resulting from the experience gained from this study, are suggested for further research:

1. That comparable times of the work day be adhered to for the methods of observation.

2. That experienced workers be compared with those of less experience.

3. That other types of jobs involving different elements be included for study.

4. That a closed circuit television system be used to provide more flexibility of sampling worker behavior at different times of the day.

APPENDICES

APPENDIX I

CHARACTERISTICS AND BACKGROUND OF THE OPERATORS

OPERATOR	A	B	C
Sex:	Female	Female	Female
Age:	52	42	40
Marital Status:	Married	Married	Married
Children:	Yes	Yes	Yes
Social background:	Middle income class		
Time working with the company (years):	20	10	11
Time working on Run on Collar:	20	10	11
Emotional stability:	Normal	Normal	Normal
Character:	Agreeable	Agreeable	Agreeable
Sociability:	High	High	High
Efficiency rate:	High	Fair	High

Total number of girls working in the Assembly Room: 400

Total number of girls engages in Run on Collar operation: 30

APPENDIX II

TIME STUDY SUMMARY SHEET

Product Shirt

Plant Atlanta

Dept Assembly	Unit Dosen	Work Prod. Per Hr. 8.20	Machine Model Singer 400W	Date October 6, 1960	
	Base Rate $1.360		Oper. Desc. Run on Collar		
	Piece Rate .1659		R.P.M. 5000 Stc./In. 12		
	Observer H.P.R.			Style All Wash & Wear	Fabric RH Band Lining

No.	SEQUENCE OF ELEMENTS	Selected Time	Rating	Normal Minutes	Occurence	Element and Minutes per Unit
1.	Get parts from rear chute (2'), place on table.			.098	1/2	.049
2.	Clip coupon, mark number and return control ticket to parts bundle.			.270	1/2	.135
3.	Remove collars, count and place under machine arch, check for size.			.200	1/2	.100
4.	Get shirts from rear chute (2') and place across lap, check size stamp on tail.			.135	1/2	.068
5.	Shove parts bundle down forward chutes.			.036	1/2	.018
6.	Shove previous shirt down chute. Pick up shirt from lap, breaking connecting join thread and place on machine.			.071	12/1	.852
7.	Pick up collar (right hand), position to shirt and both to needle.			.086	12/1	1.032
8.	Backstitch, align and stitch to center of collar					
	(A) Stitch - 9 1/8" x 12 SPI - .022 + .01 Back-stitch + .005 to Align - .037 (Accel. & Dec.)					
	5000 RPM .077 + .037	114	133	.151	12/1	1.812

APPENDIX II (continued)

TIME STUDY SUMMARY SHEET

Product Shirt Plant Atlanta

Dept Assembly	Unit Dozen	Work Prod. Per Hr. 8.20	Machine Model Singer 400W	Date October 6, 1960	
	Base Rate $1.360		Oper. Desc. Run on Collar		
	Piece Rate .1659		R.P.M. 5000 / Stc./In. 12		
	Observer H.P.R.			Style All Wash & Wear	Fabric RH Band Lining

No.	SEQUENCE OF ELEMENTS	Selected Time	Rating	Normal Minutes	Occurence	Element and Minutes per Unit
	(B) Align and break apart previous shirt - .077					
9.	Stitch to within 2" of end (align as stitch).					
	(A) Stitch - 7" x 12 SPI - .017 + .010 to align					
	- .027 (Accel. & Dec.)					
	5000 RPM	.635	133	.113	12/1	1.356
	(B) Align collar to shirt, during stitch stops					
	- .058.					
10.	Align band end, fold over open end of facing (see					
	element #12, Summary Sheet dated 9/25/53 by VHW)					
	as necessary, stitch complete and backstitch.					
	(A) Align band end and fold over facing if necessary	.039	133			
				.085	12/1	1.020
	(B) Stitch - 2" x 12 SPI - .010 + .005 + .01	.025	133			
	Backstitch - 2500 RPM					

APPENDIX III

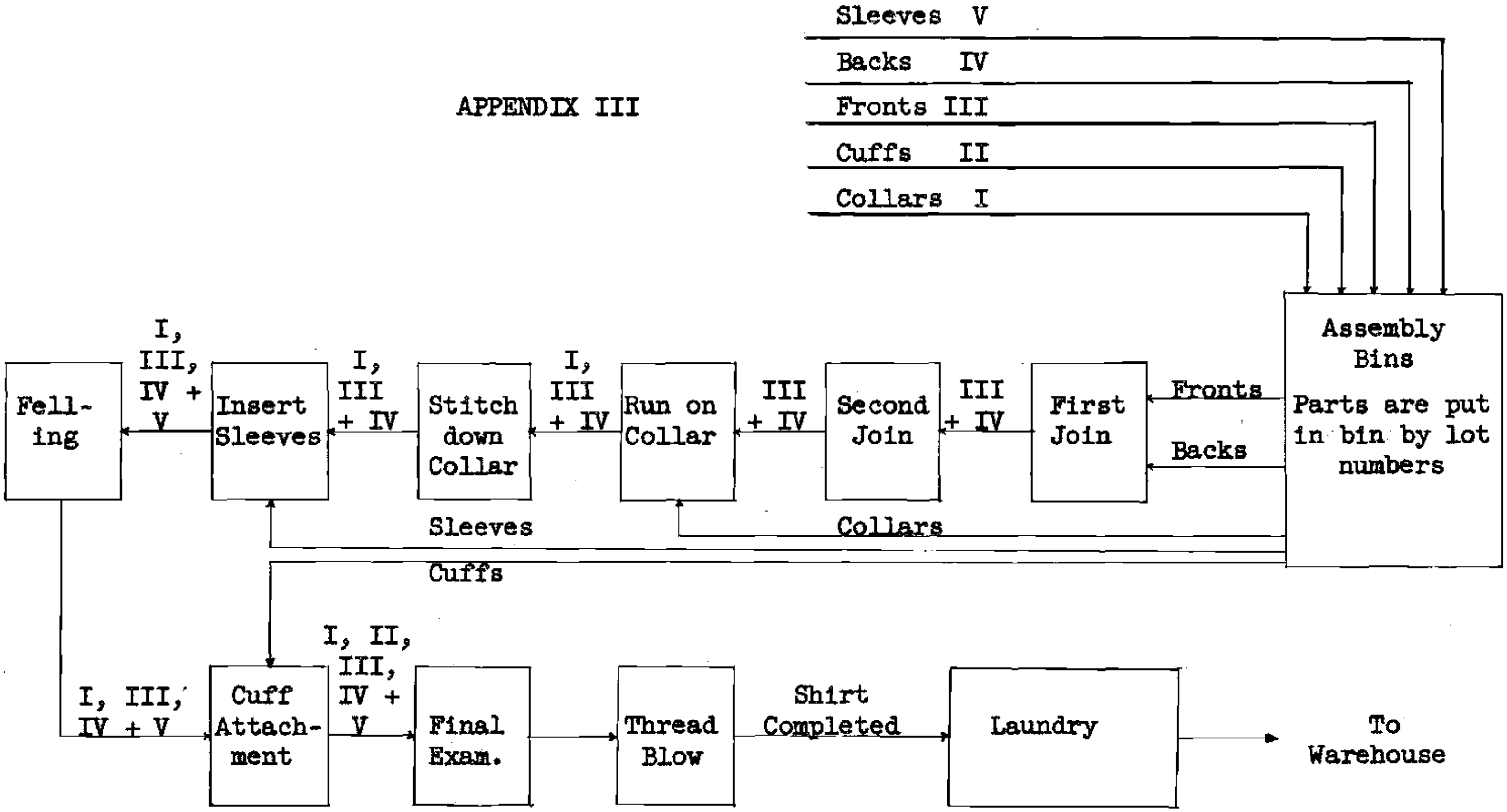


Fig. 4 Flow Process Chart

A P P E N D I X   I V

Table No. 1 a Worker A

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	15	0.60	35	15 1/2	0.62
2	15	0.60	36	16	0.64
3	13	0.52	37	14 1/2	0.58
4	15	0.60	38	15	0.60
5	15	0.60	39	15	0.60
6	21	0.84	40	15	0.60
7	14 1/2	0.58	41	16	0.64
8	15 1/2	0.62	42	13	0.52
9	15 1/2	0.62	43	15	0.60
10	15	0.60	44	16	0.64
11	15	0.60	45	15	0.60
12	13	0.52	46	15	0.60
13	15	0.60	47	14	0.56
14	14	0.56	48	17	0.68
15	14	0.56	49	17	0.68
16	14	0.56	50	17 1/2	0.70
17	15	0.60	51	17 1/2	0.70
18	15	0.60	52	18	0.72
19	8 1/2	0.34	53	15	0.60
20	20	0.80	54	19	0.76
21	15	0.60	55	12 1/2	0.50
22	20 1/2	0.82	56	14 1/2	0.58
23	18 1/2	0.74	57	17	0.68
24	15	0.60	58	16	0.64
25	16	0.64	59	17	0.68
26	15	0.60	60	18	0.72
27	18	0.72	61	15 1/2	0.62
28	19	0.76	62	14 1/2	0.58
29	20	0.80	63	14 1/2	0.58
30	14	0.56	64	17	0.68
31	18	0.72	65	17	0.68
32	16 1/2	0.66	66	14	0.56
33	17 1/2	0.70	67	20	0.80
34	15 1/2	0.62	68	13	0.52

Table No. 1 a   Worker A (cont.)

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
69	15	0.60	103	16	0.64
70	14	0.56	104	22	0.88
71	18 1/2	0.74	105	16	0.64
72	18	0.72	106	18 1/2	0.74
73	17	0.68	107	14 1/2	0.58
74	15	0.60	108	12	0.48
75	13	0.52	109	15	0.60
76	13 1/2	0.54	110	11	0.44
77	15	0.60	111	13 1/2	0.54
78	15	0.60	112	14 1/2	0.58
79	14	0.56	113	12	0.48
80	16	0.64	114	10 1/2	0.42
81	14	0.56	115	14	0.56
82	12 1/2	0.50	116	15	0.60
83	17 1/2	0.70	117	15 1/2	0.62
84	16	0.64	118	14	0.56
85	12 1/2	0.50	119	14 1/2	0.58
86	14 1/2	0.58	120	15	0.60
87	14	0.56	121	13	0.52
88	16	0.64	122	13 1/2	0.54
89	16	0.64	123	16	0.64
90	14	0.56	124	15 1/2	0.62
91	16	0.64	125	16 1/2	0.66
92	15 1/2	0.62	126	15 1/2	0.62
93	17	0.68	127	16	0.64
94	15	0.60	128	15	0.60
95	15	0.60	129	13	0.52
96	17 1/2	0.70	130	17	0.68
97	16 1/2	0.66	131	13	0.52
98	16	0.64	132	15 1/2	0.62
99	16	0.64	133	13 1/2	0.54
100	18	0.72	134	22	0.88
101	13	0.52	135	18	0.72
102	15	0.60	136	10	0.40

Table No. 1 a Worker A (cont.)

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
137	18 1/2	0.74	171	18 1/2	0.74
138	17 1/2	0.70	172	16 1/2	0.66
139	18 1/2	0.74	173	18	0.72
140	15	0.60	174	15 1/2	0.62
141	16	0.64	175	9 1/2	0.38
142	15	0.60	176	15 1/2	0.62
143	17	0.68	177	13 1/2	0.54
144	18 1/2	0.74	178	13	0.52
145	14	0.56	179	13 1/2	0.54
146	14	0.56	180	14	0.56
147	14	0.56	181	16	0.64
148	15	0.60	182	15	0.60
149	14	0.56	183	14	0.56
150	14	0.56	184	16	0.64
151	13 1/2	0.54	185	16	0.64
152	18 1/2	0.74	186	15 1/2	0.62
153	14	0.56	187	15	0.60
154	14 1/2	0.58	188	16 1/2	0.66
155	15 1/2	0.62	189	16	0.64
156	13 1/2	0.54	190	17 1/2	0.70
157	14	0.56	191	17 1/2	0.70
158	12	0.48	192	16 1/2	0.66
159	21 1/2	0.86	193	15	0.60
160	15	0.60	194	14 1/2	0.58
161	13	0.52	195	13 1/2	0.54
162	14 1/2	0.58	196	17 1/2	0.70
163	14	0.56	197	15	0.60
164	15	0.60	198	16 1/2	0.66
165	15 1/2	0.62	199	15	0.60
166	15	0.60	200	15	0.60
167	17	0.68	201	13 1/2	0.54
168	17	0.68	202	15	0.60
169	14	0.56	203	16	0.64
170	16	0.64			

Table No. 1 b Worker A (cont.)

Memomotion Data for Cycles

Within 45 Minutes Immediately Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	13	0.52	35	15	0.60
2	12	0.48	36	11	0.64
3	16 1/2	0.66	37	10	0.40
4	15	0.60	38	8	0.32
5	18	0.72	39	12 1/2	0.50
6	15 1/2	0.62	40	11 1/2	0.46
7	18	0.72	41	15	0.60
8	15 1/2	0.62	42	21	0.84
9	20	0.80	43	11	0.44
10	19	0.76	44	11 1/2	0.46
11	21 1/2	0.86	45	11 1/2	0.46
12	14	0.56	46	11	0.44
13	12	0.48	47	11	0.44
14	11 1/2	0.46	48	10	0.40
15	11 1/2	0.46	49	7	0.28
16	12	0.48	50	11	0.44
17	19 1/2	0.78	51	13	0.52
18	14	0.56	52	7	0.28
19	16 1/2	0.66	53	10	0.40
20	11 1/2	0.46	54	12	0.48
21	13	0.52	55	13	0.52
22	10	0.40	56	16	0.64
23	10	0.40	57	16	0.64
24	11 1/2	0.46	58	10	0.40
25	11 1/2	0.46	59	12 1/2	0.50
26	13 1/2	0.54	60	10	0.40
27	11 1/2	0.46	61	14 1/2	0.58
28	13 1/2	0.54	62	17	0.68
29	20	0.80	63	11 1/2	0.46
30	17	0.68	64	11	0.44
31	10	0.40	65	9	0.36
32	10	0.40	66	10	0.40
33	10	0.40	67	12	0.48
34	10	0.40	68	11	0.44

Table No. 1 b Worker A (cont.)

Memomotion Data for Cycles

Within 45 Minutes Immediately Before Time Study

Observation No.	Frames	Time (min.)
69	11	0.44
70	16	0.64
71	8	0.32
72	11 1/2	0.46
73	10	0.40
74	13	0.52
75	10	0.40
76	10	0.40
77	10	0.40
78	9	0.36
79	9	0.36
80	11	0.44
81	10	0.40
82	10	0.40
83	9	0.36
84	11	0.44
85	10	0.40

Table No. 1 c Worker A (cont.)

Memomotion Data for Cycles

on Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	11 1/2	0.46	35	11	0.44
2	11 1/2	0.46	36	11	0.44
3	13	0.52	37	10	0.40
4	9 1/2	0.38	38	10 1/2	0.42
5	10	0.40	39	13	0.52
6	11 1/2	0.46	40	10	0.40
7	10	0.40	41	15	0.60
8	11 1/2	0.46	42	13 1/2	0.54
9	9 1/2	0.38	43	6 1/2	0.26
10	9	0.36	44	10	0.40
11	9	0.36	45	12	0.48
12	17 1/2	0.70	46	9	0.36
13	11 1/2	0.46	47	10	0.40
14	10	0.40	48	10	0.40
15	12	0.48	49	10	0.40
16	9	0.36	50	10	0.40
17	10	0.40	51	9	0.36
18	10	0.40	52	8	0.32
19	11	0.44	53	13	0.52
20	8	0.32	54	10	0.40
21	10	0.40	55	9	0.36
22	9	0.36	56	10	0.40
23	9	0.36	57	7	0.28
24	10	0.40	58	11	0.44
25	9	0.36	59	8 1/2	0.34
26	8 1/2	0.34	60	10	0.40
27	10 1/2	0.42	61	8 1/2	0.34
28	9	0.36	62	11	0.44
29	8	0.32	63	8 1/2	0.34
30	9	0.36	64	10 1/2	0.42
31	11	0.44	65	10	0.40
32	11	0.44	66	10	0.40
33	10	0.40	67	9	0.36
34	10	0.40	68	8	0.32

Table No. 1 c   Worker A (cont.)

Memomotion Data for Cycles

on Time Study

Observation No.	Frames	Time (min.)
69	8 1/2	0.34
70	9 1/2	0.38
71	12 1/2	0.50
72	7 1/2	0.30
73	10 1/2	0.42
74	10 1/2	0.42
75	7 1/2	0.30
76	10 1/2	0.42
77	12	0.48
78	7	0.28
79	9	0.36
80	12	0.48
81	8	0.32
82	7 1/2	0.30
83	9 1/2	0.38
84	9 1/2	0.38
85	9 1/2	0.38
86	8	0.32
87	11	0.44
88	7 1/2	0.30
89	13 1/2	0.54
90	9	0.36
91	6 1/2	0.26
92	9	0.36
93	6 1/2	0.26
94	9 1/2	0.38
95	10	0.40
96	7	0.28
97	10	0.40
98	11 1/2	0.46
99	9	0.36

Table No. 2 a Worker B

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	17	0.68	35	15	0.60
2	16	0.64	36	12	0.48
3	14	0.56	37	15	0.60
4	14	0.56	38	14	0.56
5	12	0.48	39	12	0.48
6	17	0.68	40	12	0.48
7	16 1/2	0.66	41	14	0.56
8	15	0.60	42	16	0.64
9	16	0.64	43	16	0.64
10	16	0.64	44	16 1/2	0.66
11	14	0.56	45	16	0.64
12	14	0.56	46	16	0.64
13	14	0.56	47	16	0.64
14	15	0.60	48	16 1/2	0.66
15	16 1/2	0.66	49	17 1/2	0.70
16	9	0.36	50	16	0.64
17	9 1/2	0.38	51	16	0.64
18	12	0.48	52	18	0.72
19	14	0.56	53	19	0.76
20	14	0.56	54	18	0.72
21	14	0.56	55	17	0.68
22	12	0.48	56	17	0.68
23	15	0.60	57	16 1/2	0.66
24	17 1/2	0.70	58	17	0.68
25	17 1/2	0.70	59	14	0.56
26	17 1/2	0.70	60	15	0.60
27	19	0.76	61	14	0.56
28	16	0.64	62	14	0.56
29	16	0.64	63	16	0.64
30	16	0.64	64	17	0.68
31	15 1/2	0.62	65	14	0.56
32	12	0.48	66	14	0.56
33	13	0.52	67	15	0.60
34	15	0.60	68	17	0.68

Table No. 2 a   Worker B (cont.)

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
69	13	0.52	103	14	0.56
70	14	0.56	104	14	0.56
71	15	0.60	105	14 1/2	0.58
72	12	0.48	106	13	0.52
73	11	0.44	107	13 1/2	0.54
74	15	0.60	108	17	0.68
75	14	0.56	109	17 1/2	0.70
76	14 1/2	0.58	110	13	0.52
77	15	0.60	111	16	0.64
78	12	0.48	112	13	0.52
79	11	0.44	113	14	0.56
80	13	0.52	114	15	0.60
81	14	0.56	115	15	0.60
82	13	0.52	116	12	0.48
83	15 1/2	0.62	117	14	0.56
84	15 1/2	0.62	118	17 1/2	0.70
85	15	0.60	119	11	0.44
86	14 1/2	0.58	120	10	0.40
87	16	0.64	121	12	0.48
88	16	0.64	122	14	0.56
89	16 1/2	0.66	123	11	0.44
90	15	0.60	124	13	0.52
91	17	0.68	125	9	0.36
92	14	0.56	126	12 1/2	0.50
93	17	0.68	127	16	0.64
94	14	0.56	128	17 1/2	0.70
95	17	0.68	129	14	0.56
96	17	0.68	130	15	0.60
97	16 1/2	0.66	131	15	0.60
98	14	0.56	132	14	0.56
99	12	0.48	133	14 1/2	0.58
100	16 1/2	0.66	134	15	0.60
101	14	0.56	135	14	0.56
102	13	0.52	136	13 1/2	0.54

Table No. 2 a   Worker B (cont.)

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
137	13 1/2	0.54	171	14	0.56
138	13	0.52	172	14	0.56
139	13 1/2	0.54	173	14 1/2	0.58
140	14	0.56	174	10	0.40
141	14	0.56	175	13 1/2	0.54
142	15	0.60	176	14	0.56
143	15 1/2	0.62	177	12 1/2	0.50
144	14	0.56	178	15	0.60
145	14	0.56	179	14	0.56
146	13	0.52			
147	13 1/2	0.54			
148	18	0.72			
149	13 1/2	0.54			
150	13	0.52			
151	14	0.56			
152	14	0.56			
153	15 1/2	0.62			
154	17	0.68			
155	16 1/2	0.66			
156	16	0.64			
157	13	0.52			
158	14	0.56			
159	13 1/2	0.54			
160	9	0.36			
161	9 1/2	0.38			
162	14	0.56			
163	13	0.52			
164	10	0.40			
165	13	0.52			
166	13 1/2	0.54			
167	14	0.56			
168	14	0.56			
169	15 1/2	0.62			
170	16	0.64			

Table No. 2 b Worker B

Memomotion Data for Cycles

on Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	7 1/2	0.30	35	9	0.36
2	11	0.44	36	9	0.36
3	8	0.32	37	9	0.36
4	10	0.40	38	9 1/2	0.38
5	8 1/2	0.34	39	9 1/2	0.38
6	7 1/2	0.30	40	9	0.36
7	15	0.60	41	10	0.40
8	9	0.36	42	10 1/2	0.42
9	10	0.40	43	11	0.44
10	9	0.36	44	6 1/2	0.26
11	11	0.44	45	9	0.36
12	11	0.44	46	12 1/2	0.50
13	9	0.36	47	14	0.56
14	9	0.36	48	11	0.44
15	9	0.36	49	12 1/2	0.50
16	9	0.36	50	8 1/2	0.34
17	9	0.36	51	9	0.36
18	9	0.36	52	8	0.32
19	10	0.40	53	8	0.32
20	7 1/2	0.30	54	9	0.36
21	9	0.36	55	9 1/2	0.38
22	9	0.36	56	14	0.56
23	9	0.36	57	11	0.44
24	9	0.36	58	11	0.44
25	8 1/2	0.34	59	10 1/2	0.42
26	9	0.36	60	10 1/2	0.42
27	9	0.36	61	10 1/2	0.42
28	13 1/2	0.54	62	9	0.36
29	9	0.36	63	9	0.36
30	7 1/2	0.30	64	9	0.36
31	10	0.40	65	8 1/2	0.34
32	10 1/2	0.42	66	8 1/2	0.34
33	11	0.44	67	9	0.36
34	11	0.44	68	10	0.40

Table No. 2 b   Worker B (cont.)

Memomotion Data for Cycles

on Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
69	13	0.52	103	9	0.36
70	12 1/2	0.50	104	9 1/2	0.38
71	13	0.52	105	8 1/2	0.34
72	11	0.44			
73	8	0.32			
74	8 1/2	0.34			
75	9	0.36			
76	9	0.36			
77	8 1/2	0.34			
78	8	0.32			
79	9	0.36			
80	9	0.36			
81	9	0.36			
82	10	0.40			
83	11	0.44			
84	9	0.36			
85	9 1/2	0.38			
86	12	0.48			
87	9	0.36			
88	9	0.36			
89	10	0.40			
90	9 1/2	0.38			
91	9	0.36			
92	8	0.32			
93	8	0.32			
94	9 1/2	0.38			
95	8 1/2	0.34			
96	10	0.40			
97	10	0.40			
98	9 1/2	0.36			
99	9	0.36			
100	9	0.36			
101	9 1/2	0.38			
102	8 1/2	0.34			

Table No. 2 c   Worker B

Memomotion Data for Cycles

Immediately Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	14	0.56	35	12	0.48
2	13 1/2	0.54	36	11 1/2	0.46
3	12	0.48	37	13 1/2	0.54
4	14	0.56	38	13	0.52
5	14	0.56	39	12	0.48
6	19	0.76	40	12	0.48
7	14	0.56	41	11	0.44
8	12	0.48	42	11	0.44
9	13	0.52	43	11	0.44
10	19	0.36	44	11	0.44
11	11	0.44	45	9	0.36
12	11	0.44	46	17	0.68
13	14	0.56	47	15	0.60
14	9 1/2	0.38	48	16 1/2	0.66
15	10	0.40	49	17	0.68
16	14	0.56	50	12	0.48
17	11	0.44	51	12 1/2	0.50
18	12	0.48	52	12 1/2	0.50
19	9	0.36	53	11	0.44
20	9	0.36	54	11 1/2	0.46
21	10	0.40	55	11 1/2	0.46
22	11 1/2	0.46	56	12	0.48
23	12	0.48	57	12	0.48
24	11	0.44	58	12 1/2	0.50
25	11 1/2	0.46	59	12	0.48
26	11 1/2	0.46	60	13	0.52
27	12	0.48	61	13 1/2	0.54
28	14	0.56	62	13	0.52
29	12	0.48			
30	12	0.48			
31	11	0.44			
32	17	0.68			
33	15	0.60			
34	12	0.48			

Table No. 2 d Worker B

Memomotion Data for Cycles

Within 3/4 Hour Immediately After Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	13	0.52	35	10	0.40
2	12	0.48	36	8	0.32
3	10 1/2	0.42	37	9	0.36
4	9 1/2	0.38	38	9	0.36
5	7	0.28	39	9 1/2	0.38
6	7 1/2	0.30	40	10	0.40
7	8 1/2	0.34	41	9 1/2	0.38
8	8 1/2	0.34	42	9	0.36
9	10 1/2	0.42	43	9	0.36
10	10 1/2	0.42	44	10	0.40
11	8 1/2	0.34	45	10	0.40
12	11	0.44	46	12 1/2	0.50
13	13 1/2	0.54	47	14	0.56
14	9 1/2	0.38	48	12 1/2	0.50
15	8 1/2	0.34	49	15	0.60
16	8 1/2	0.34	50	12	0.48
17	8	0.32	51	12 1/2	0.50
18	8	0.32	52	16	0.64
19	9	0.36			
20	10	0.40			
21	7 1/2	0.30			
22	7 1/2	0.30			
23	8	0.32			
24	8 1/2	0.34			
25	8 1/2	0.34			
26	10 1/2	0.42			
27	14	0.56			
28	9	0.36			
29	8 1/2	0.34			
30	10	0.40			
31	6	0.24			
32	10 1/2	0.42			
33	10	0.40			
34	10	0.40			

Table No. 3 a Worker C

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	18	0.72	35	13	0.52
2	19	0.76	36	14	0.56
3	17 1/2	0.70	37	14 1/2	0.58
4	13 1/2	0.54	38	16	0.64
5	18	0.72	39	16	0.64
6	15	0.60	40	11	0.44
7	17	0.68	41	18 1/2	0.74
8	17 1/2	0.70	42	19	0.76
9	19	0.76	43	19	0.76
10	18	0.72	44	13	0.52
11	14	0.56	45	16	0.64
12	12	0.48	46	14	0.56
13	12 1/2	0.50	47	17 1/2	0.70
14	16	0.64	48	17	0.68
15	16	0.64	49	18	0.72
16	18	0.72	50	17 1/2	0.74
17	19 1/2	0.78	51	15	0.60
18	13	0.52	52	16 1/2	0.66
19	12	0.48	53	15	0.60
20	15	0.60	54	16 1/2	0.66
21	12	0.48	55	16	0.64
22	18	0.72	56	17 1/2	0.70
23	17	0.68	57	17	0.68
24	17 1/2	0.70	58	14 1/2	0.58
25	17 1/2	0.70	59	15	0.60
26	17	0.68	60	16	0.64
27	18	0.72	61	16 1/2	0.66
28	18	0.72	62	16	0.64
29	15	0.60	63	16 1/2	0.66
30	19	0.76	64	17	0.68
31	16	0.64	65	15	0.60
32	16	0.64	66	15	0.60
33	11	0.44	67	12 1/2	0.50
34	11 1/2	0.46	68	13	0.52

Table No. 3 a Worker C (cont.)

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
69	13	0.52	103	21	0.84
70	13 1/2	0.54	104	14	0.56
71	14	0.56	105	12	0.48
72	18	0.72	106	12	0.48
73	16	0.64	107	11 1/2	0.46
74	16	0.64	108	11 1/2	0.46
75	12	0.48	109	13	0.52
76	12	0.48	110	12	0.48
77	11 1/2	0.46	111	12 1/2	0.50
78	12	0.48	112	9	0.36
79	12	0.48	113	9	0.36
80	12	0.48	114	10 1/2	0.42
81	12	0.48	115	11	0.44
82	11 1/2	0.46	116	11	0.44
83	12	0.48	117	11 1/2	0.46
84	11 1/2	0.46	118	13	0.52
85	11 1/2	0.46	119	12 1/2	0.50
86	12	0.48	120	15	0.60
87	13	0.52	121	15	0.60
88	12 1/2	0.50	122	16	0.64
89	13 1/2	0.54	123	16 1/2	0.66
90	12	0.48	124	10	0.40
91	14	0.56	125	17	0.68
92	10	0.40	126	16 1/2	0.66
93	10 1/2	0.42	127	16 1/2	0.66
94	11	0.44	128	17 1/2	0.70
95	11	0.44	129	14	0.56
96	11 1/2	0.46	130	21	0.84
97	11 1/2	0.46	131	17 1/2	0.70
98	11 1/2	0.46	132	17	0.68
99	12	0.48	133	16	0.64
100	12	0.48	134	15	0.60
101	12 1/2	0.50	135	14	0.56
102	19	0.76	136	14 1/2	0.58

Table No. 3 a Worker C (cont.)

Memomotion Data for Cycles

Within 2 Weeks Before Time Study

Observation No.	Frames	Time (min.)
137	13 1/2	0.54
138	14	0.56
139	13 1/2	0.54
140	12	0.48
141	14 1/2	0.58
142	14 1/2	0.58
143	11	0.44
144	9	0.36
145	10	0.40
146	15	0.60
147	14 1/2	0.58
148	16	0.64
149	15	0.60
150	10	0.40
151	12	0.48
152	12 1/2	0.50
153	11 1/2	0.46
154	14 1/2	0.58
155	14 1/2	0.58
156	14	0.56
157	13 1/2	0.54
158	13	0.52
159	13	0.52
160	13 1/2	0.54
161	12	0.48
162	14 1/2	0.58
163	13 1/2	0.54
164	12 1/2	0.50
165	13 1/2	0.54
166	13 1/2	0.54
167	19	0.76
168	17	0.68
169	18	0.72
170	19	0.76

Table No. 3 b Worker C

Memomotion Data for Cycles

on Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	12	0.48	35	11 1/2	0.46
2	12 1/2	0.50	36	7	0.28
3	9	0.36	37	12	0.48
4	9 1/2	0.38	38	11	0.44
5	11	0.44	39	14	0.56
6	11 1/2	0.46	40	11 1/2	0.46
7	10	0.40	41	10	0.40
8	10	0.40	42	15	0.60
9	10	0.40	43	11	0.44
10	11 1/2	0.46	44	12 1/2	0.50
11	9 1/2	0.38	45	12	0.48
12	13	0.52	46	11	0.44
13	13 1/2	0.54	47	7	0.28
14	12	0.48	48	9	0.36
15	11 1/2	0.46	49	9 1/2	0.38
16	11 1/2	0.46	50	10	0.40
17	11	0.44	51	10 1/2	0.42
18	10	0.40	52	10	0.40
19	10 1/2	0.42	53	10	0.40
20	11	0.44	54	11	0.44
21	11 1/2	0.46	55	11	0.44
22	10	0.40	56	12	0.48
23	10 1/2	0.42	57	9	0.36
24	12	0.48	58	10	0.40
25	9	0.36	59	10 1/2	0.42
26	9 1/2	0.38	60	10 1/2	0.42
27	11	0.44	61	10 1/2	0.42
28	11 1/2	0.46	62	10 1/2	0.42
29	11 1/2	0.46	63	10	0.40
30	11 1/2	0.46	64	9	0.36
31	11	0.44	65	11	0.44
32	10 1/2	0.42	66	10 1/2	0.42
33	7 1/2	0.30	67	10 1/2	0.42
34	10	0.40	68	10	0.40

Table No. 3 b Worker C (cont.)

Memomotion Data for Cycles

on Time Study

Observation No.	Frames	Time (min.)
69	12	0.48
70	11	0.44
71	11	0.44
72	10	0.40
73	11 1/2	0.46
74	10 1/2	0.42
75	10 1/2	0.42
76	11	0.44
77	14	0.56
78	16	0.64
79	9	0.36
80	10	0.40
81	10 1/2	0.42
82	10 1/2	0.42
83	11 1/2	0.46
84	11 1/2	0.46
85	11	0.44
86	11	0.44
87	11 1/2	0.46
88	12	0.48
89	8	0.32
90	11	0.44
91	10 1/2	0.42
92	10 1/2	0.42
93	14	0.56
94	12	0.48
95	13	0.52
96	10 1/2	0.42
97	12	0.48
98	11 1/2	0.46

Table No. 3 c Worker C

Memomotion Data for Cycles

Immediately After Time Study

Observation No.	Frames	Time (min.)	Observation No.	Frames	Time (min.)
1	12	0.48	35	11	0.44
2	11	0.44	36	11 1/2	0.46
3	11	0.44	37	10	0.40
4	11 1/2	0.46	38	10 1/2	0.42
5	16	0.64	39	11	0.44
6	9	0.36	40	14	0.56
7	11 1/2	0.46	41	13	0.52
8	12	0.48	42	13 1/2	0.54
9	11	0.44	43	10	0.40
10	10	0.40	44	10 1/2	0.42
11	9 1/2	0.38	45	10 1/2	0.42
12	9 1/2	0.38	46	9	0.36
13	10	0.40	47	10 1/2	0.42
14	9 1/2	0.38	48	15	0.60
15	10	0.40	49	10 1/2	0.42
16	11	0.44	50	11	0.44
17	11	0.44	51	11 1/2	0.46
18	12	0.48			
19	9	0.36			
20	10	0.40			
21	10 1/2	0.42			
22	10 1/2	0.42			
23	10 1/2	0.42			
24	10 1/2	0.42			
25	14	0.56			
26	12	0.48			
27	13 1/2	0.54			
28	9	0.36			
29	9 1/2	0.38			
30	9 1/2	0.38			
31	9 1/2	0.38			
32	9 1/2	0.38			
33	9	0.36			
34	10	0.40			

Table 4 a

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 5 a

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
10	1		1	1	.52		
9	0	1	1	2	1.01		
8	0	0	0	2	1.01		
7	2	0	2	4	2.02		
6	3	2	5	7	4.55		
5	1	3	4	13	6.58		
4	4	1	5	18	9.10		
3	6	4	10	28	14.15		
2	8	6	14	42	21.20		
1	7	8	15	57	28.80		
0	24	7	31	88	44.40		
- 1	7	24	31	119	60.00		
- 2	16	7	23	142	71.80		
- 3	5	16	21	163	82.20		
- 4	6	5	11	174	88.00		
- 5	4	6	10	184		14	8.6
- 6	3	4	7	191		7	5.2
- 7	2	3	5	196		2	2.6
		2	2	198			

Step 3: Total 99 Step 4 divided by 2 (Step 3) = 2 x 99 = 198

Table 4 b

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 5 b

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
14	1		1	1	.246		
13	1	1	2	3	.74		
12	1	1	2	5	1.20		
11	1	1	2	7	1.72		
10	3	1	4	11	2.71		
9	0	3	3	14	3.44		
8	2	0	2	16	3.94		
7	8	2	10	26	6.40		
6	8	8	16	42	10.25		
5	9	8	17	59	14.50		
4	12	9	21	80	19.70		
3	7	12	19	99	23.40		
2	24	7	31	130	32.00		
1	15	24	39	169	41.60		
0	43	15	58	227	55.80		
- 1	11	43	54	281	69.00		
- 2	23	11	34	315	77.50		
- 3	11	23	34	349	85.08		
- 4	11	11	22	371		35	8.6
- 5	3	11	14	385		21	5.18
- 6	3	3	6	391		15	3.7

Table 4 b (continued)

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 5 b

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
- 7	0	3	3	394		12	2.95
- 8	1	0	1	395		11	2.71
- 9	1	1	2	397		9	2.12
-10	1	1	2	399		7	1.73
-11	2	1	3	402		4	.98
-12	0	2	2	404		2	.49
-13	0	0	0	406			
-14	0	0					
	1	1					

Step 3: Total 203 Step 4 = 2(Step 3) = 2 x 203 = 406

Table 5 a

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 6 a

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
11	1		1	1	.475		
10	0	1	1	2	.950		
9	1	0	1	3	1.425		
8	1	1	2	5	2.375		
7	2	1	3	8	3.810		
6	3	2	5	13	6.20		
5	1	3	4	17	8.20		
4	0	1	1	18	8.60		
3	11	0	11	29	13.80		
2	5	11	16	45	21.40		
1	10	5	15	60	28.60		
0	13	10	23	83	39.60		
- 1	37	13	50	133	64.90		
- 2	8	37	45	178	84.80		
- 3	7	8	15	193		17	8.20
- 4	4	7	11	204		6	2.85
- 5	0	4	4	208		2	.95
- 6	1	0	1	209		1	.475
		1	1	210			

Step 3: Total 105   Step 4 = 2(Step 3) = 2(105) = 210

Table 5 b

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 6 b

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter Column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
10	2		2	2	.56		
9	0	2	2	4	1.11		
8	3	0	3	7	1.95		
7	8	3	11	18	5.00		
6	12	8	20	38	11.55		
5	8	12	20	58	16.10		
4	17	8	25	83	23.10		
3	6	17	23	106	29.60		
2	20	6	26	132	36.80		
1	5	20	25	157	43.80		
0	45	5	50	207	57.80		
- 1	10	45	55	262	69.00		
- 2	15	10	25	287	80.00		
- 3	2	15	17	304	85.00		
- 4	13	2	15	319	89.1		
- 5	0	13	13	332		26	7.25
- 6	4	0	4	336		22	6.1

Table 5 b (continued)

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 6 b

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency <u>above</u> the measurement mid-point	Cumulative per cent <u>above</u> the measurement mid-point	Twice the cumulative frequency <u>below</u> the measurement mid-point	Cumulative per cent <u>below</u> the measurement mid-point
Select	Count	Enter Column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
- 7	0	4	4	340		18	5
- 8	4	0	4	344		14	3.75
- 9	2	4	6	350		8	2.2
-10	3	2	5	355		3	.8
		3	3	358			

Step 3: Total 179 Step 4 = 2 x 179 = 358

Table 6 a

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 7 a

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter Column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
9	1		1	1	.52		
8	0	1	1	2	1.04		
7	3	0	3	5	2.55		
6	1	3	4	9	4.60		
5	2	1	3	12	6.12		
4	2	2	4	16	8.18		
3	11	2	13	29	14.8		
2	15	11	26	55	28		
1	17	15	32	87	44.3		
0	17	17	34	121	61.7		
- 1	15	17	32	153	78.0		
- 2	4	15	19	172	87.8		
- 3	6	4	10	182		14	7.15
- 4	0	6	6	188		8	4.08
- 5	1	0	1	189		7	3.57
- 6	1	1	2	191		6	3.06
- 7	2	1	3	194		2	1.04
		2	2	196			

Step 3: Total 98 Step 4 = 2 x 98 = 196

Table 6 b

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 7 b

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter Column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
15	2		2	2	.58		
14	0	2	2	4	1.16		
13	0	0	0	4	1.16		
12	2	0	2	6	1.74		
11	7	2	9	15	4.4		
10	1	7	8	23	6.75		
9	10	1	11	34	10		
8	9	10	19	53	15.6		
7	9	9	18	71	20.8		
6	6	9	15	86	25.2		
5	15	6	22	108	31.8		
4	0	15	15	123	36.2		
3	13	0	13	136	40.0		
2	9	13	22	158	46.5		
1	10	9	19	177	52.0		
0	10	10	20	197	57.8		
- 1	10	10	20	217	63.8		
- 2	9	10	19	236	69.2		

Table 6 b (continued)

Worksheet for Construction of the Distribution Curve

Histogram of Fig. 7 b

1	2	5	6	7	8	9	10
Measurement Mid-Point	Frequency			Twice the cumulative frequency above the measurement mid-point	Cumulative per cent above the measurement mid-point	Twice the cumulative frequency below the measurement mid-point	Cumulative per cent below the measurement mid-point
Select	Count	Enter Column 2. Follow the Arrow	Column 2 plus Column 5	Accumulate the values in Column 6	Column 7 divided by Step 4. Express as per cent	When Column 8 is 90 per cent or more Step 4 minus Column 7	Column 9 divided by Step 4. Express as per cent
- 3	19	9	28	264	77.8		
- 4	13	19	32	296	87.0		
- 5	7	13	20	316		24	7.1
- 6	2	7	9	325		15	4.4
- 7	4	2	6	331		9	
- 8	0	4	4	335		5	2.64
- 9	3	0	3	338		2	.58
		3	3	341			

Step 3: Total 170 Step 4 = 2 x 170 = 340

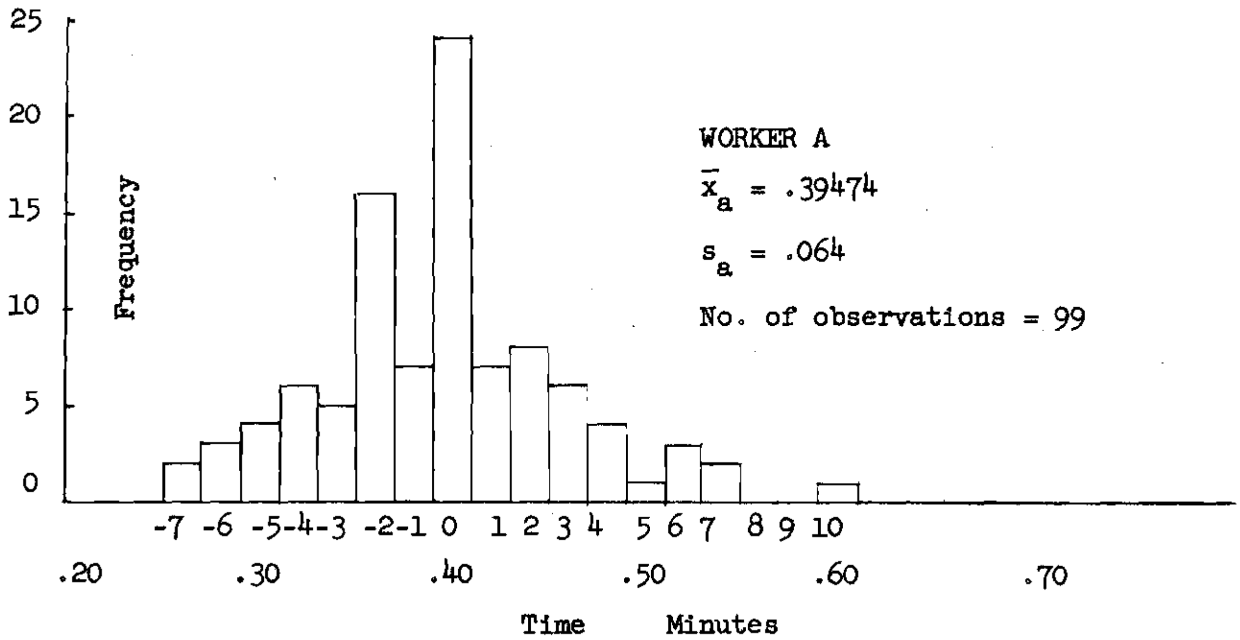


Fig. 5 a Memomotion Data for the Period While Time Studies were being Taken Data from Table 1 C

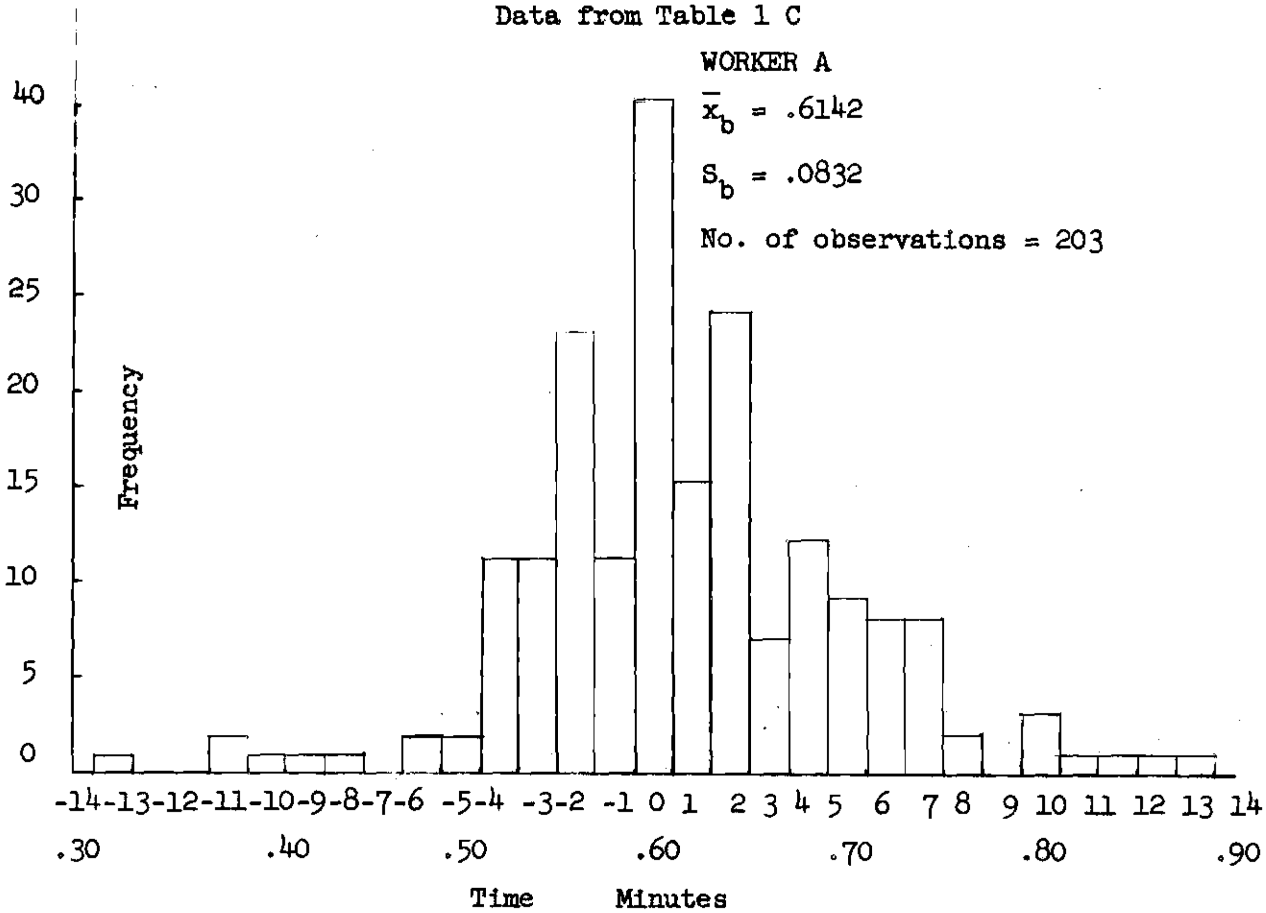


Fig. 5 b Memomotion Data for the Period Within 2 Weeks Before Time Studies were Taken Data from Table 1 A

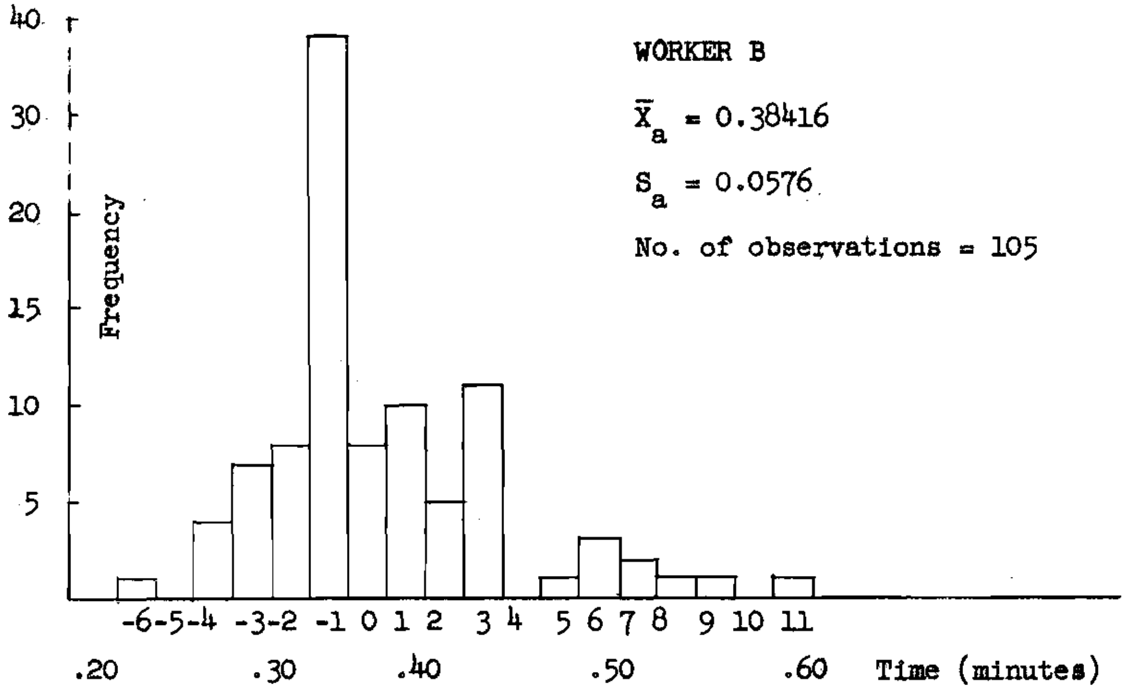


Fig. 6 a Memomotion Data for the Period While Time Studies were being Taken Data from Table 2 B

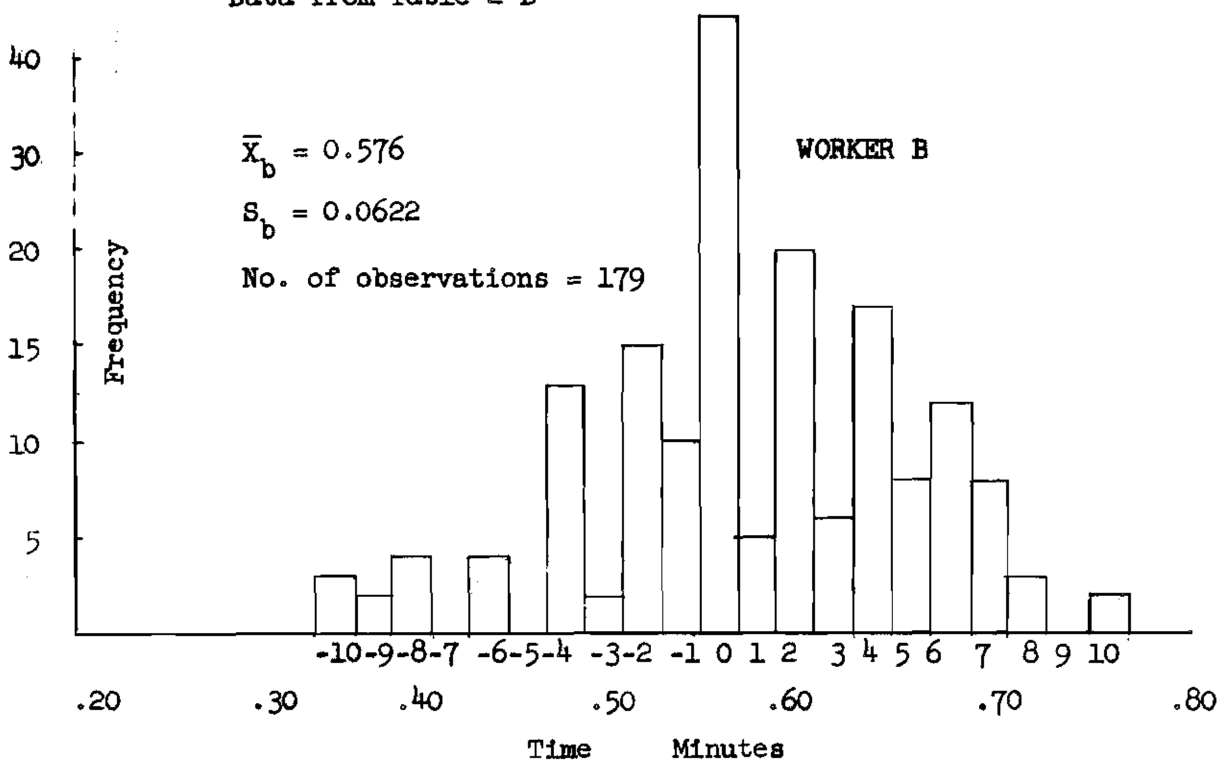


Fig. 6 b Memomotion Data for the Period Within 2 Weeks Before Time Studies were Taken Data from Table 2 A

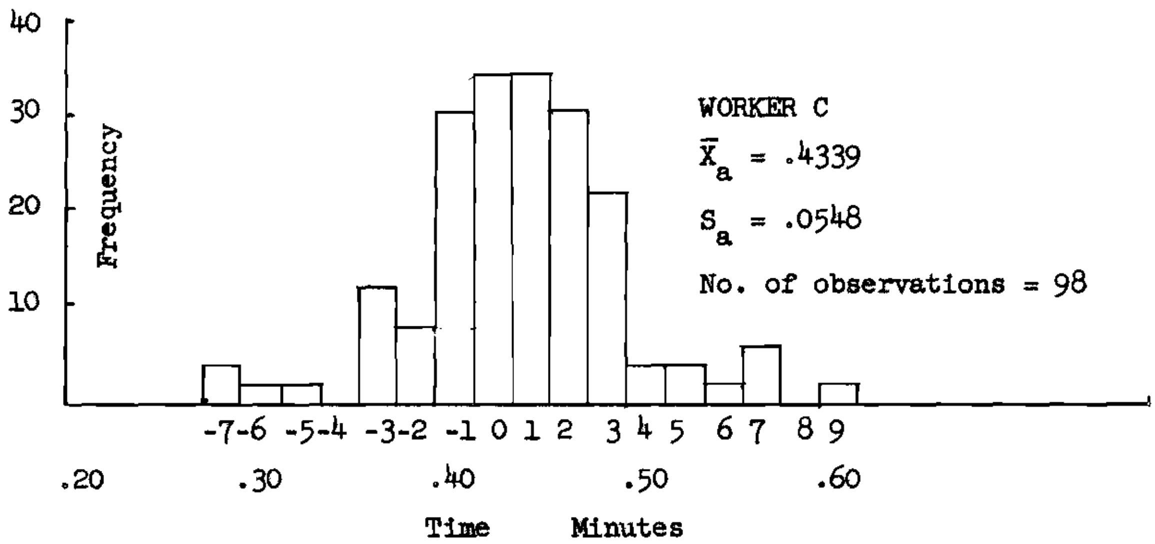


Fig. 7 a Memomotion Data for the Period While
Time Studies were Being Taken
Data from Table 3 B

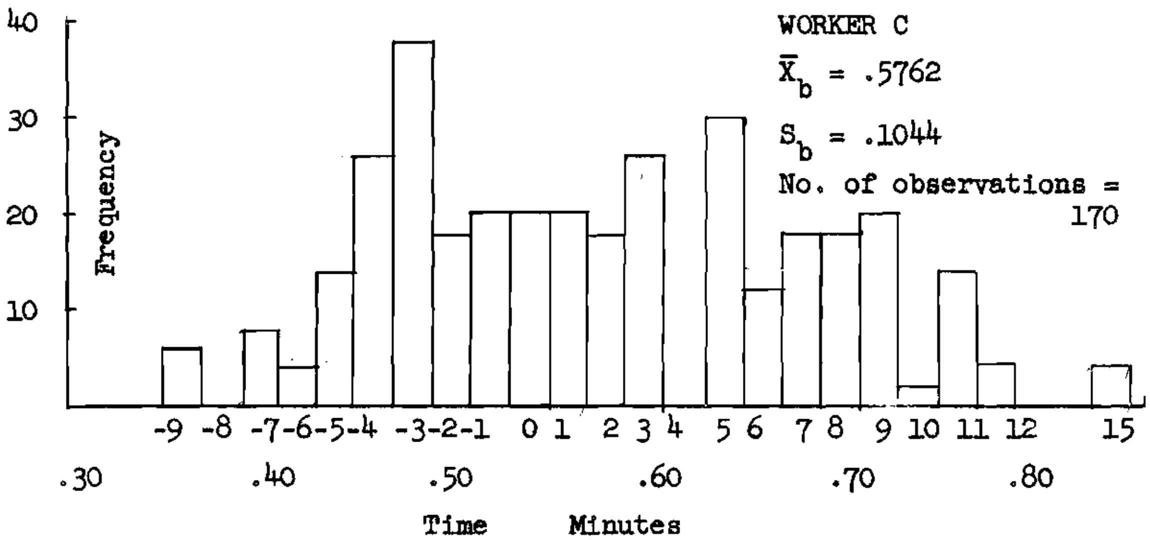


Fig. 7 b Memomotion Data for the Period Within 2 Weeks
Before Time Studies were Taken
Data from Table 3 A

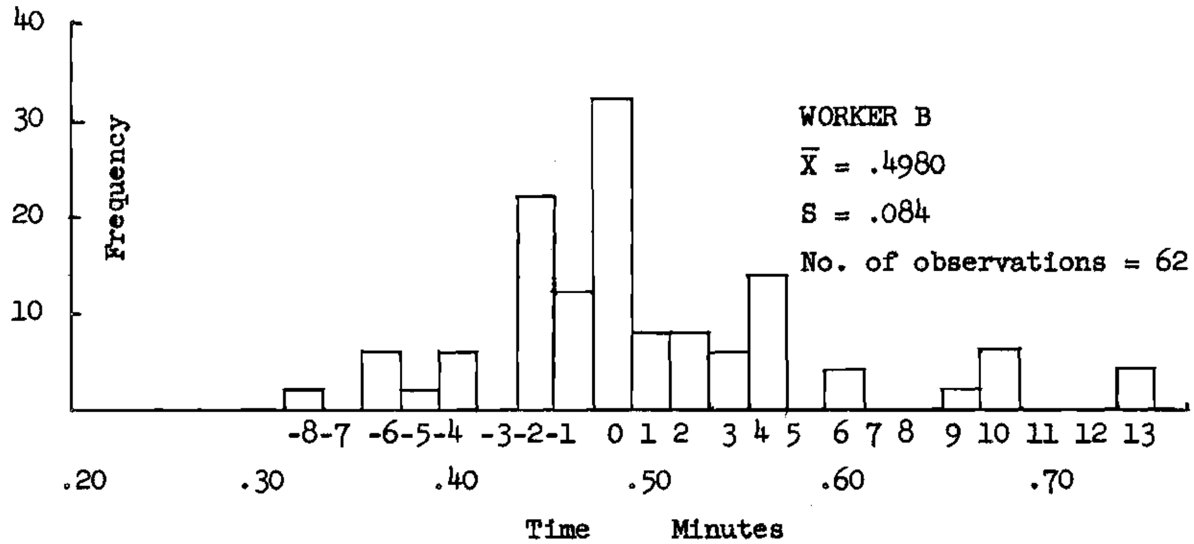


Fig. 8 a Memomotion Data for the Period 45 Minutes Immediately Before Time Studies were Taken. Data from Table 2 C

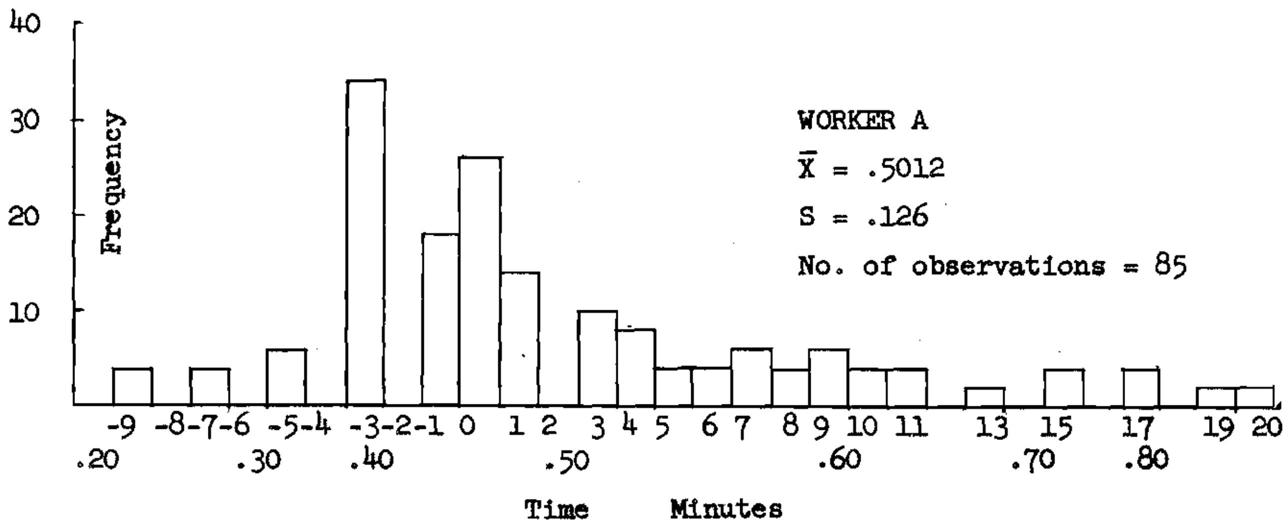


Fig. 8 b Memomotion Data for the Period 45 Minutes Immediately Before Time Studies were Taken Data from Table 1 B

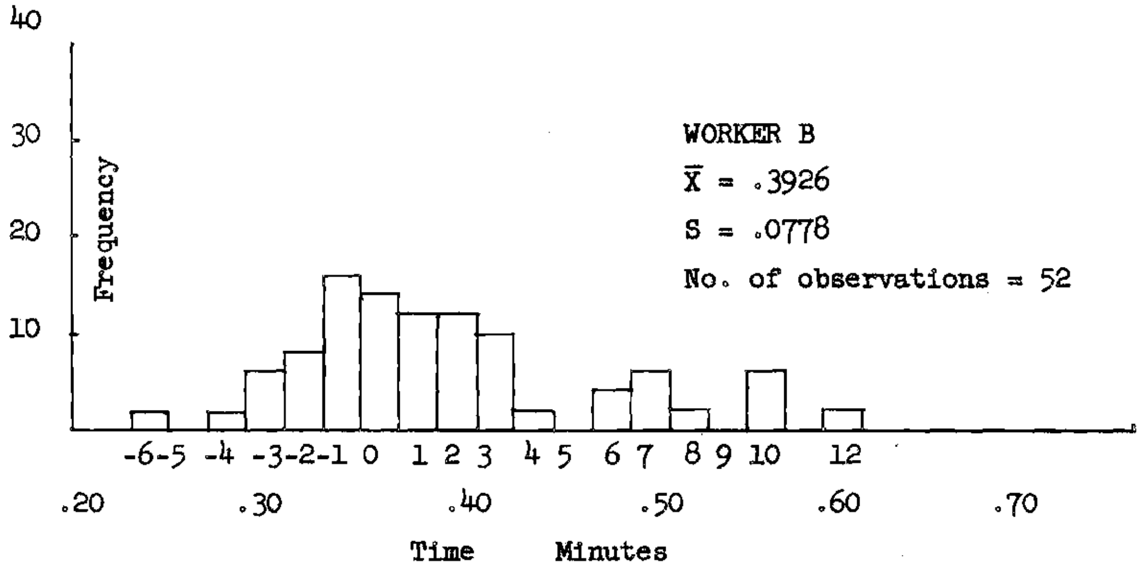


Fig. 9 a Memomotion Data for the Period 45 Minutes Immediately After Time Studies were Taken. Data from Table 2 D

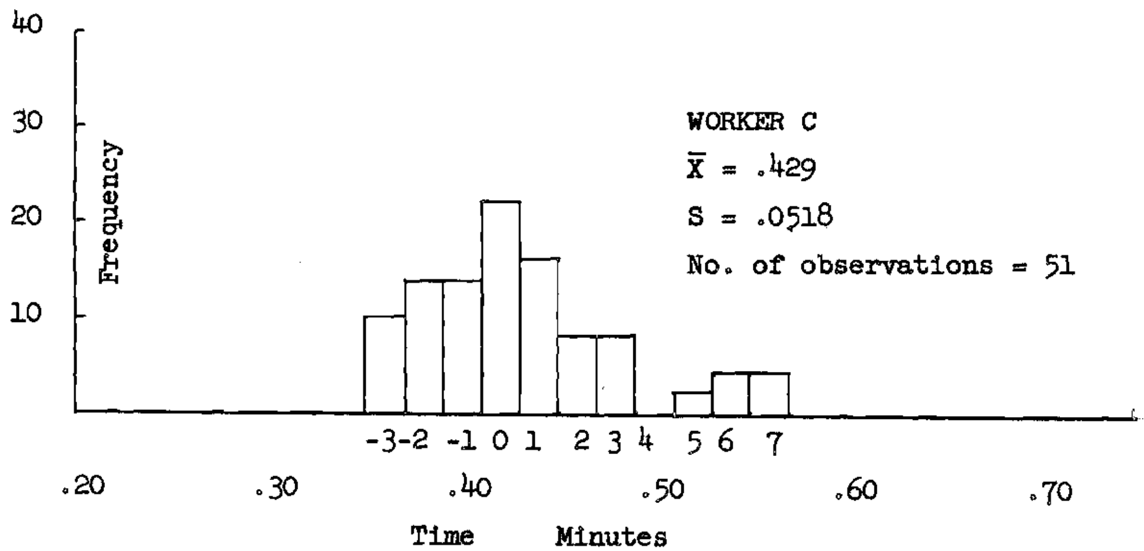


Fig. 9 b Memomotion Data for the Period 45 Minutes Immediately After Time Studies were Taken. Data from Table 3 C

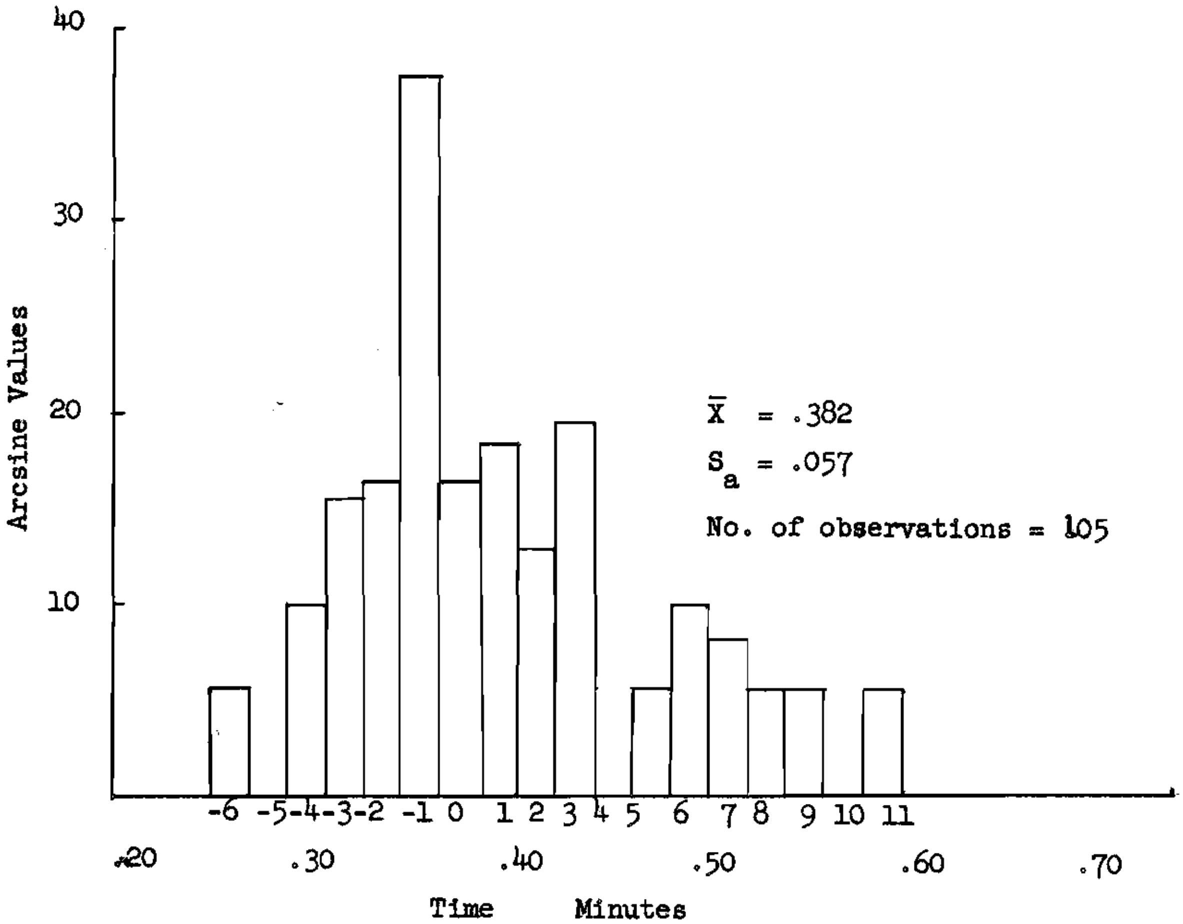


Fig. 10 Arcsine Transform of the Distribution of Fig. 6 a

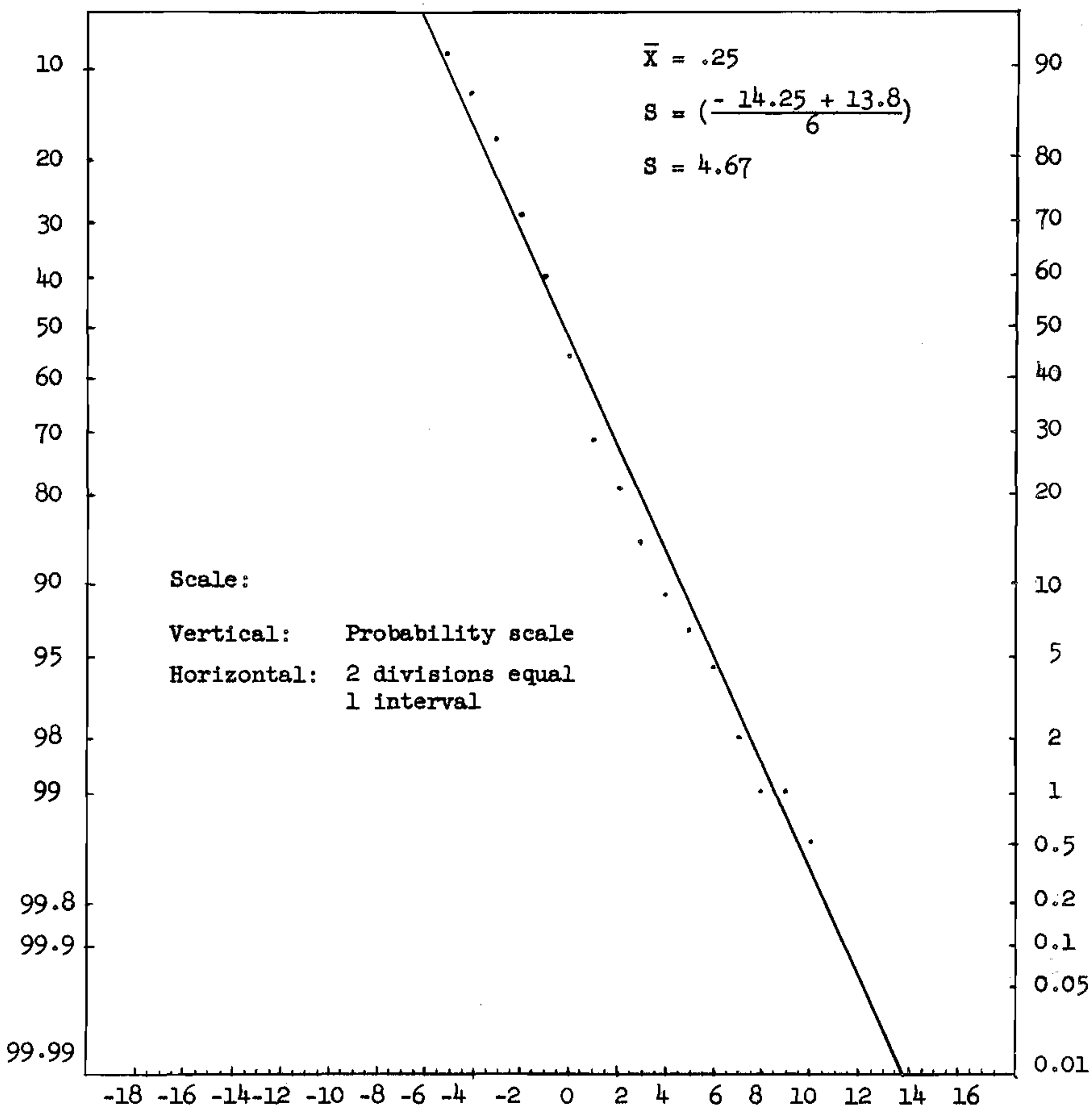


Fig. 11 Test for the Normality of the Distribution in Fig. 5 a

Values from Table 4 a

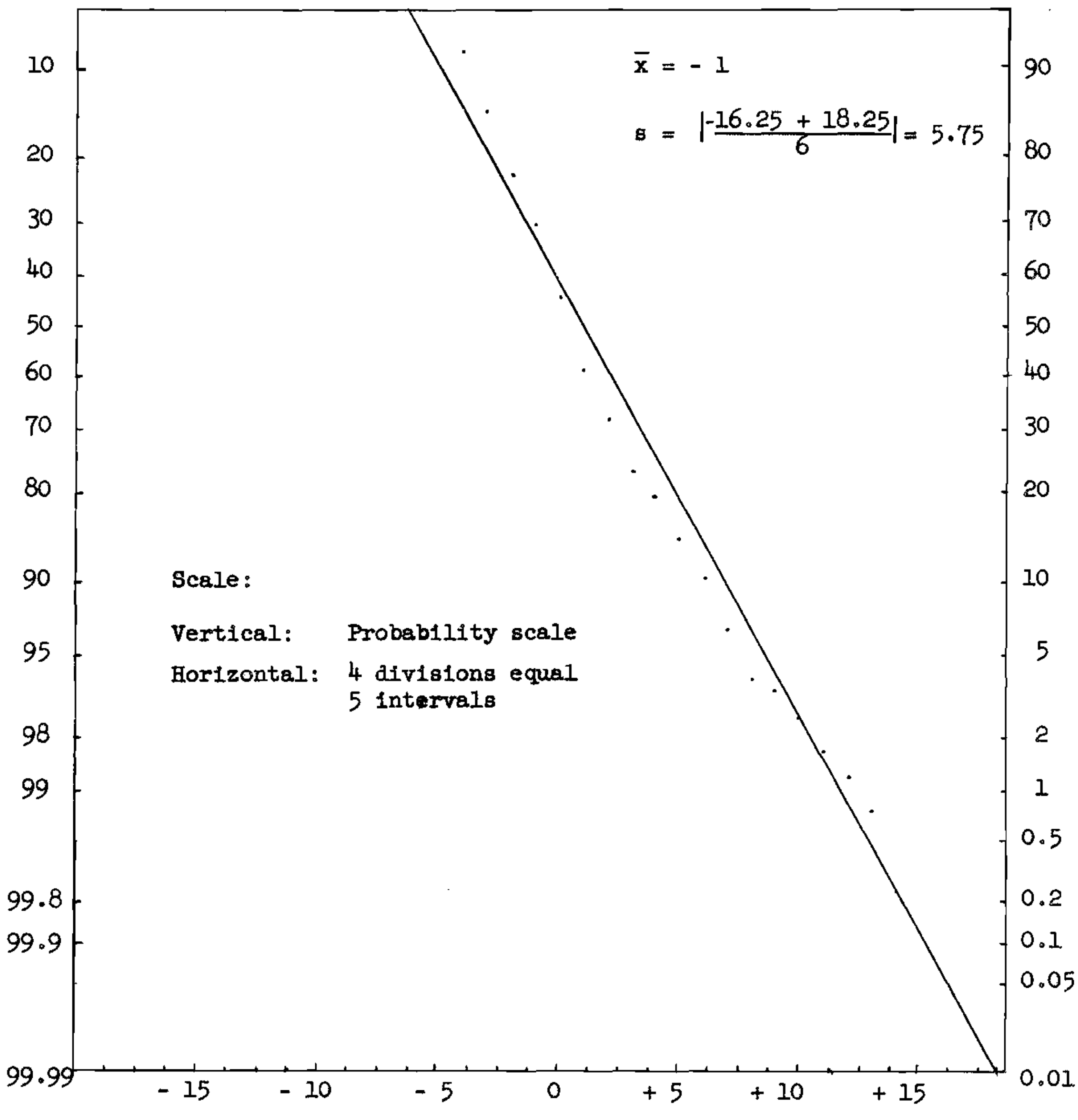


Fig. 12 Test for the Normality of the Distribution in Fig. 5 b

Values from Table 4 b

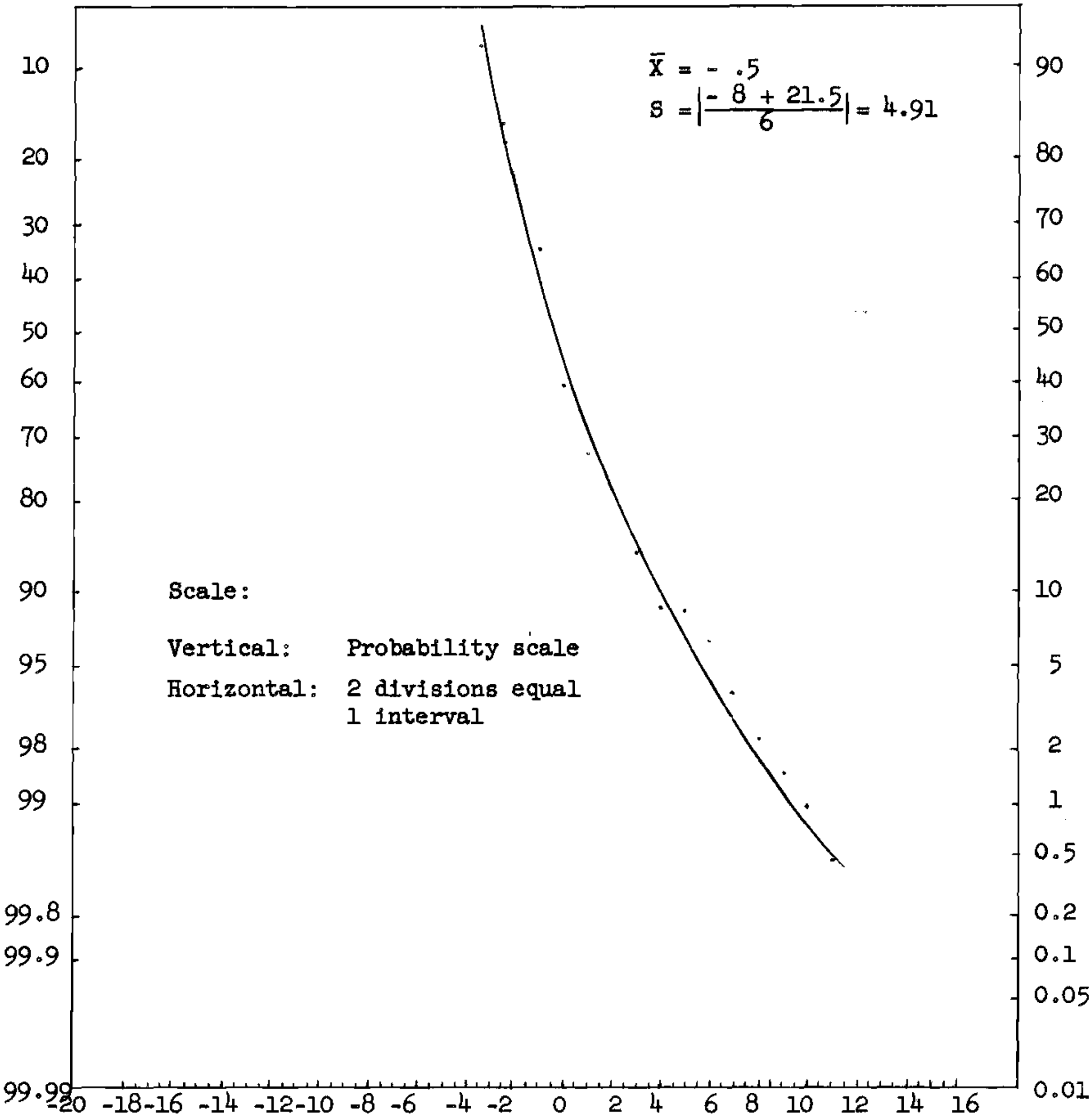


Fig. 13 Test for the Normality of the Distribution in Fig. 6 a. Values from Table 5 a

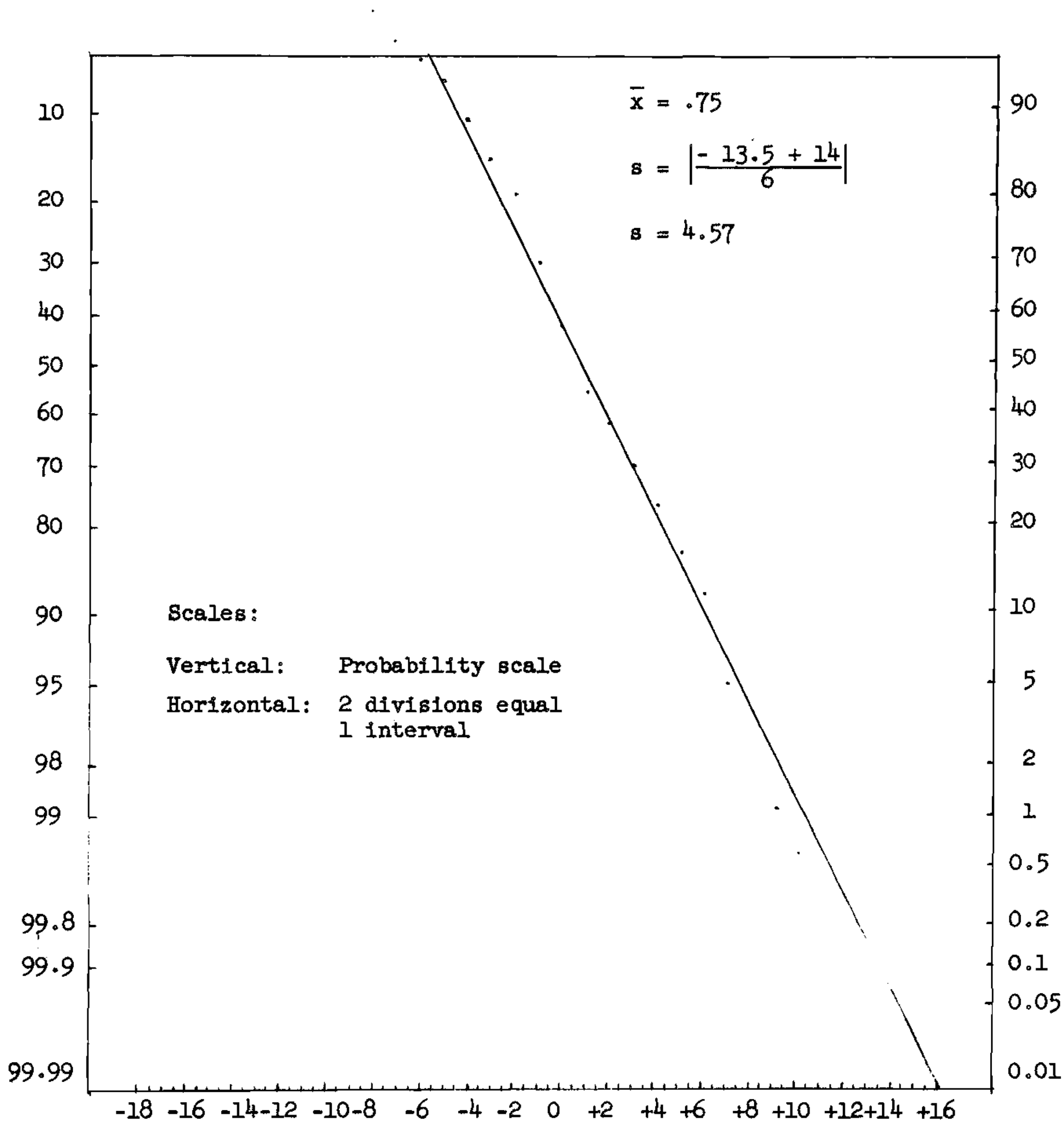


Fig. 14 Test for the Normality of the Distribution in Fig. 6 b

Values from Table 5 b

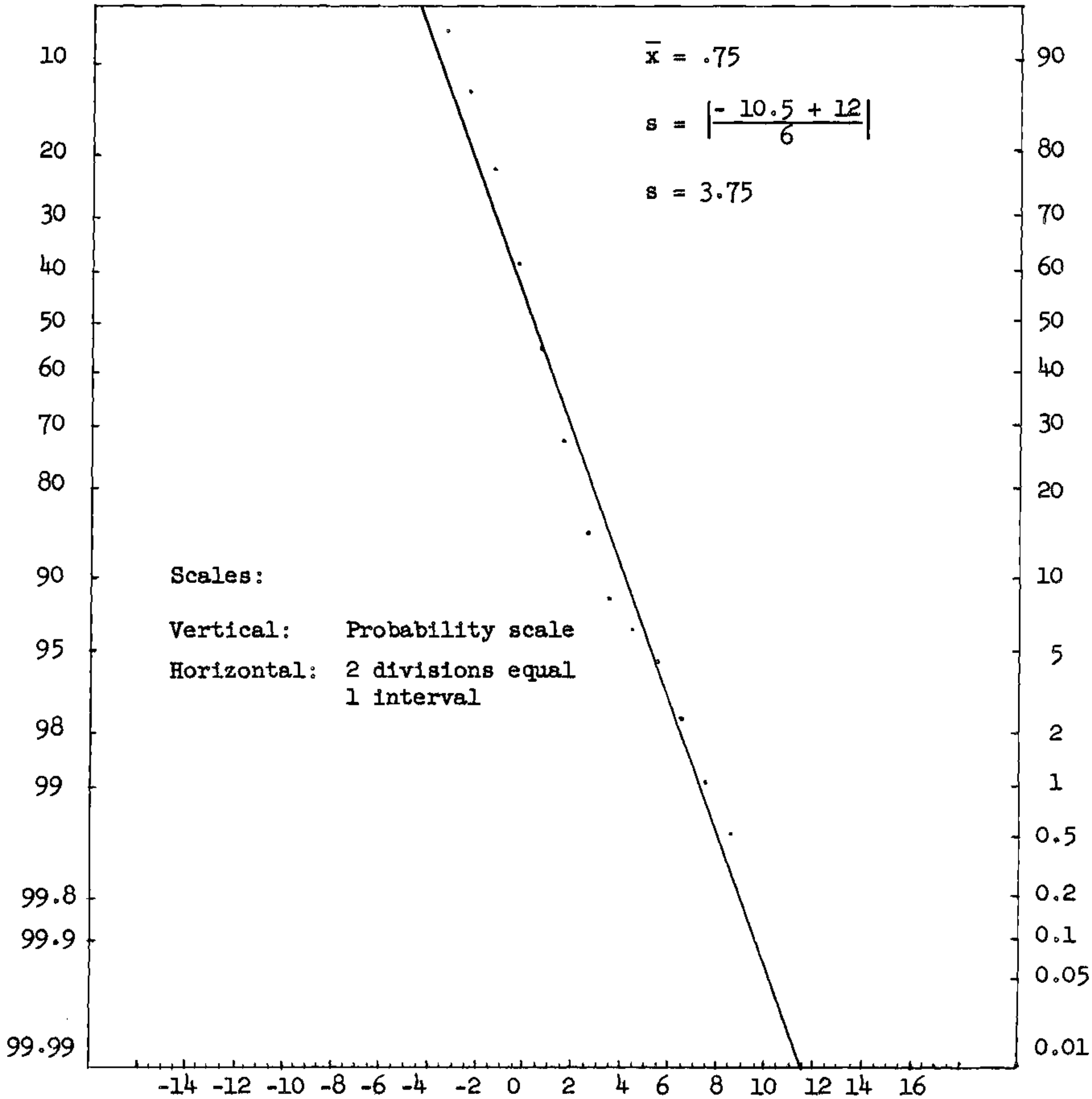


Fig. 15 Test for Normality of the Distribution in Fig. 7 a

Values from Table 6 a

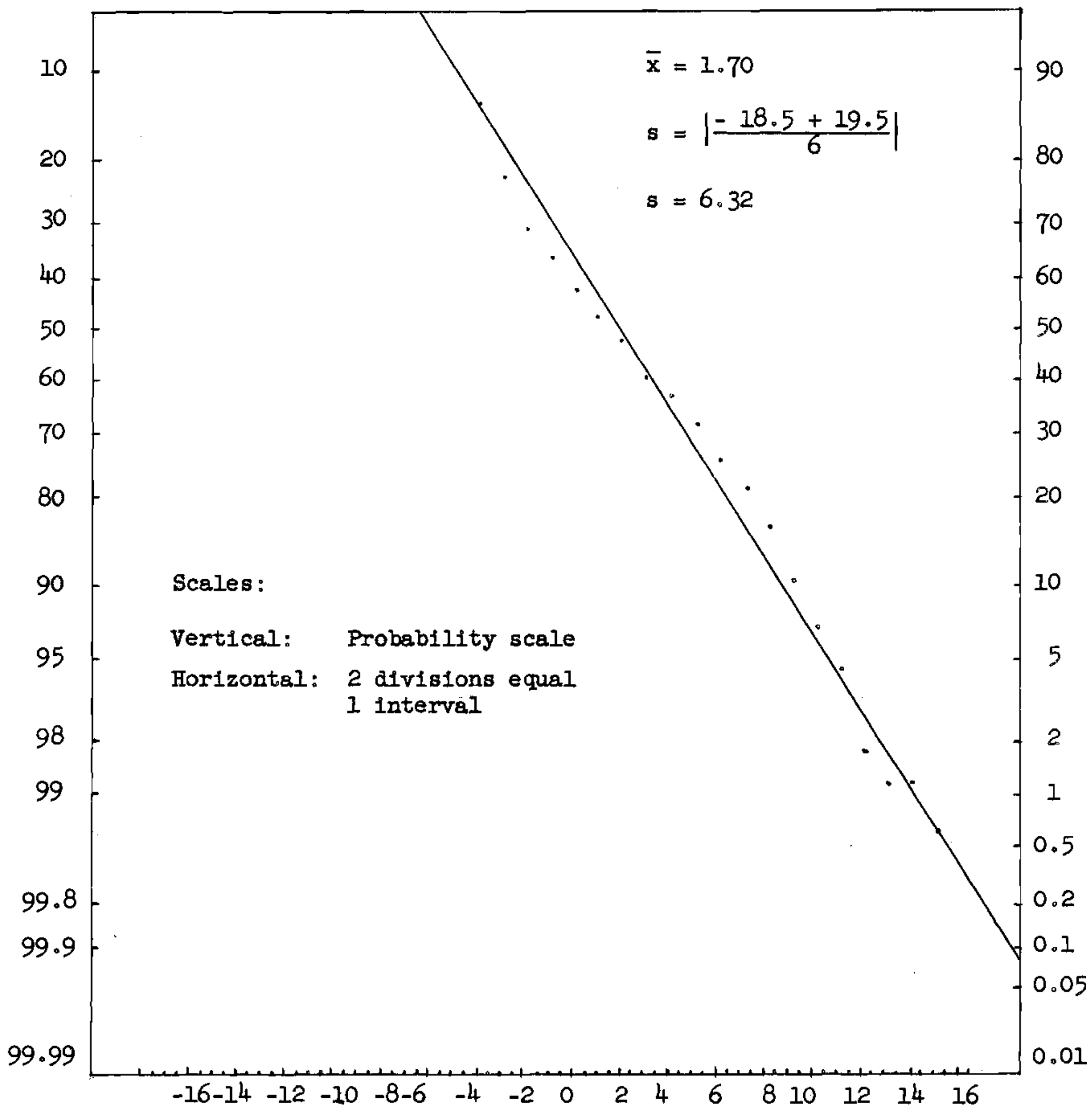


Fig. 16 Test for Normality of the Distribution in Fig. 7 b

Values from Table 6 b

F and T Tests for Worker A

A) Test for equality of the variances

H_o: $\quad_a = \quad_b$ $\qquad \alpha = .05 \qquad H_1 \quad a \neq b$

$S_a^2 = 39.96 \times 10^{-4}$

$S_b^2 = 69.12 \times 10^{-4}$

$F = \frac{S_a}{S_b} = \frac{39.96}{69.12} = .578$

Acceptance Region:

$$1/F \quad 2;\ n_b - 1\ n_a - 1,\ F \quad /2\ n_a - 1,\ n_b - 1$$

or

$$1/F_{.025;\ 203,\ 98} \leq F \leq F_{.025,\ 99,\ 203}$$

$$.71 \leq F \leq 1.39$$

$\therefore$ Reject the hypothesis that the variances are equal

B) Test for equality of the means

H_o: $M_a = M_b$

Test Statistic $\quad t' = \dfrac{\bar{x}_a - \bar{x}_b}{S_a^2/n_a + S_b^2/n_b} = \dfrac{.21946}{8.68 \times 10^{-3}} = 25.28$

and the associated degrees of freedom are:

$$\nu = \frac{(S_a^2/n_a + S_b^2/n_b)^2}{\frac{(S_a^2/n_a)^2}{n_a + 1} + \frac{(S_b^2/n_b)^2}{n_b + 1}} - 2 = 252 \qquad \begin{array}{l} n_a = 99 \\ n_b = 203 \end{array}$$

Acceptance Region:

$t \quad /2\nu \leq t' \leq t \quad /2\ \nu \qquad$ or $\qquad -1.971 \leq t' \leq 1.971$

$\therefore$ Reject the hypothesis that the means are equal

Fig. 17 Performance Before Time Study Vs. Performance on Time Study

F and t' Tests for Worker B

Data from Tables 6 a and 6 b

A) Test for equality of the variances

H_o: $_a = _b$ $\alpha = .05$

$s_a^2 = 19.5$

$s_b^2 = 20.9$

$$F = \frac{S_a}{S_b} = \frac{33.18 \times 10^{-4}}{38.69 \times 10^{-4}} = .857$$

Acceptance Region:

$$1/F_{.025,\ 179,\ 105} \leq F \leq F_{.025;\ 105,\ 179}$$

$$.62 \leq F \leq 1.405$$

$\therefore$ Accept the hypothesis that the variances are equal

B) Test for equality of the means

H_o: $M_a = M_b$

Test Statistic $$t = \frac{\bar{x}_a - \bar{x}_b}{\sqrt{\frac{1}{n_a} + \frac{1}{n_b}}\ \sqrt{\frac{\frac{n_a}{i = 1} (x_a - \bar{x}_a)^2 + \frac{n_b}{i = 1} (x_i - \bar{x}_b)^2}{n_a + n_b - 2}}} = 9.13$$

Acceptance Region:

$$t_{.025,\ 282} \leq t \leq t_{.025,\ 282}$$

$$- 1.971 \leq t \leq 1.971$$

$\therefore$ Reject the hypothesis that the means are equal at the 5% level

Fig. 18 Performance Before Time Study Vs. Performance on Time Study

F and t' Tests for Worker C

Data from Tables 7 a and 7 b

A) Test for the equality of variances

H_o: $_a = _b$ $\qquad \alpha = .05$

H_1: $_a \neq _b$

$S_a^2 = 30.04 \times 10^{-4}$

$S_b^2 = 108.94 \times 10^{-4}$

$$F = \frac{S_a}{S_b} = \frac{30.03}{108.99} = .2756$$

Acceptance Region:

$$1/F_{.025;\ 170,\ 98} \leq F \leq F_{.025;\ 98,\ 170}$$

$$.69 \leq F \leq 1.41$$

∴ Reject the hypothesis that the variances are equal at the 5% level

B) Test for equality of the means

H_o: $M_a = M_b$

Test Statistic $$t' = \frac{\bar{x}_a - \bar{x}_b}{S_a^2/u_a + S_b^2/u_b} = \frac{.1423}{9.72 \times 10^{-3}} = 14.65$$

and the associated degrees of freedom are

$$\nu = \frac{(S_a^2/n_a + S_b^2/n_b)^2}{\frac{(S_a^2/n_a)^2}{u_a + 1} + \frac{(S_b^2/n_b)^2}{u_b + 1}} - 2 = 255 \qquad n_a = 98$$

$$n_b = 170$$

Acceptance Region:

$t\ /2\ \nu \leq t' \leq .t\ /2\ \nu$ or $-1.972 \leq t' \leq 1.972$

∴ Reject the hypothesis that the means are equal at 5% level

Fig. 19 Performance Before Time Study Vs. Performance on Time Study

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