THE CURVE OF RECOVERY FROM FATIGUE IN MENTAL WORK

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Introduction

This investigation is concerned with determining the shape of the curve of recuperation from fatigue resulting from continuous mental work. "Mental work" and "fatigue" are debatable concepts. The meaning of both terms has been the subject for a great deal of controversy. Therefore, to avoid misunderstanding, these terms are defined below, as it is intended they should be interpreted throughout the study.

"Mental Work" versus "Muscular Work" - What is meant by mental work? Several attempts have been made to differentiate between "mental work" and "muscular work". Thorndike suggested that "mental work" should refer to work of the "connecting system", i.e., the nervous system, as opposed to physical work, the work of sense organs and muscles. But such a distinction falls down practically. For the lifting of a weight is muscular work even though it does involve the nervous system, and solving arithmetic problems is "mental work" even though sensitive instruments show that it involves muscular contraction. Watson maintains that mental work involves implicit behavior or activity of the finer skeletal muscles, smooth muscles and glands, and that physical work involves overt behavior or activity of the gross muscles of the body. Bills (10, p. 414) believes, "that the most satisfactory answer is that the distinction between physical work and mental is purely one of degree; the former involving relatively more use of the gross muscles and the latter involving relatively more use of the finer muscles and the nervous system". "Mental work" as predominance of implicit behavior is the definition accepted by this author.

<u>Fatigue</u> - "Fatigue" is equally as ambiguous a term as mental work. It can refer to at least three entirely different, and, to a certain extent, independent things: First, the subjective experience of the worker; second, that decrement in the quantity or quality of the output which results from the continuity of the work and is regained during rest; third, organic change. In the words of Bills, (9, p. 438) "fatigue in mental work means a measurable decrement in either output or organic state or subjective feeling-tone resulting from the continuous performance of intellectual work involving implicit behavior predominantly".

<u>Recuperation</u> - Fatigue disappears following freedom from the mental work which produced it. This period subsequent to the cessation of mental work is the recuperation period during which some or all of the efficiency lost during continuous work is regained. Now fatigue in the foregoing was identified with a decrement in either output, organic state or subjective feeling-tone. Recovery may therefore be identified with an increment in either output, organic state or subjective feeling-tone. It is with the problem of recovery from fatigue that the author of the present work is in the main concerned.

<u>Measurements of Fatigue</u> - Each of the three different aspects of fatigue requires its own measuring device and criteria. Subjective fatigue is measured by means of a rating scale based on the worker's introspective report. Organic fatigue is measured in terms of quantitative change in metabolism. Objective fatigue or decrement in output is studied by either the continuous work method or the interpolated task method. We are interested here only in the former <u>method</u>. According

to this method, a continuous record is kept of the output of the subject per unit time throughout the period of work. A work curve is then plotted from these values showing the change in level of performance of the subject in successive units of time. The criteria of efficiency of performance most commonly used are speed and accuracy or some other criterion of quality of output. Let it just be mentioned in passing that the work curve has certain well-established characteristics, but these will be taken up later.

Studies on Recovery - Just as the curve of learning has, as its corollary, the curve of forgetting, so the curve of work should have its corollary in the curve of recovery. But little systematic data have been compiled from which a curve could be plotted. The first important study of recovery after rest, concerned rest in human muscle. It was made by Maggiora (64) in 1890 and according to Manzer has become a classic. He studied the flexor muscles of the middle finger of both hands. He found that if, after a half hour of work with a rhythm of ten seconds, work were done at a two second rhythm, the record thus obtained showed no difference either in the form of the curve or in the amount of the mechanical work done from another record made by the same muscle when completely rested.

In another study Maggiora found that a rest pause of two hours is sufficient to prevent the accumulation of fatigue and to secure from the muscle, in the evening as well as in the morning, the quantity of mechanical work which it is capable of producing under conditions of complete rest.

Weiler (107), using a spring dynamometer of his own design, studied recovery after rest in the muscles involved in grasping. In one condition of the experiment, sixty uninterrupted contractions with a two-second rhythm were made. In the second condition, a rest of two minutes was inserted after the thirtieth contraction. His results showed that work done in the first half of the two series was practically equal, whereas, a decrease in the second half of 41.8 per cent occurred when no rest was taken as compared with a decrease of only 17 per cent in the second half when a two minute rest was inserted. The rest of two minutes, Weiler concluded, produced an increase in output of 24.8 per cent in the second half.

It was Manzer (65) who, in an experiment on rest pauses, plotted the curves of recovery from muscular work involved in finger, hand, arm, leg, and trunk flexions. The subjects worked to exhaustion, then rested either five, or ten, or twenty minutes, and then were tested for degree of recovery. During the rest pauses the subjects were free to do as they wished provided their activity did not involve strenuous exercise. Almost without exception the pauses were spent in the laboratory, standing or sitting conversing with other subjects or reading the newspaper. The average recovery after five minutes of rest was 82 per cent, after 10 minutes 90 per cent, and after twenty minutes 95 per cent. In other words, the curve of recovery from muscular work of this sort appears to be negatively accelerated with more than three-quarters of the recovery taking place during the first five minutes. After the twenty minute point the curve tends to become asymptotic to the level of the nonfatigued performance. Among the factors which Manzer found to influence the rate of recovery were the size of the muscle groups, the attitude of the worker, and the nearness to the exhaustion point reached during work. Small muscles, he found, recover more rapidly than large.

No published curves of recovery from mental work are available. However, evidence provided by Bills (10) indicates that the rate of recovery is also negatively accelerated.

That the subject's attitude toward work and during rest influences the recuperative value of the rest pause was first pointed out by Kraepelin's students. Graf (51) found that "the resting worker's attitude toward the resumption of work undergoes a series of changes during the rest. For the first five to ten minutes the attitude is favorable to resumption, then there is a drop in readiness followed by an ultimate rise. The optimal rest must terminate at a high point in readiness".

The method of spending the rest period has been shown by Wyatt (116) to affect the rate of recovery. He reports that when a fifteen minute rest is placed in the middle of two hours' work in addition, complete relaxation gave a gain in output of 9.3 per cent; uncontrolled rest gave 8.3 per cent; music during rest gave 3.9 per cent; tea gave 3.4 per cent; and a walk 1.5 per cent.

Up to this point, only the output decrement aspect of fatigue has been considered. The other two aspects, feeling-tone decrement and organic change, also disappear with rest. The question arises as to whether the rates of recovery in these two aspects differ from each other and whether the curve of each of these differs from the output curve? The answers to these questions are very incomplete. Poffenberger (71) found that a ten minute rest period following five and a half hours of mental work, produced an absolute improvement in feeling-tone which was fairly constant regardless of the type of task or of the amount of previous decrement which had developed. He found no clear relationship between the change in feeling-tone level and the change in output level resulting from rest.

As to recovery in organic condition Schubert (80) found, for muscular work lasting up to twenty minutes, that the excess oxygen consumed during the recovery period was a function of the length of the previous work period, and that the rate during the first three minutes of rest exceeded that during work. Thereafter it gradually fell to the resting level. As to mental work, Rounds, Schubert and Poffenberger made tests of the expired air twice during the rest period after twenty minutes' work on addition. They found that the metabolic rate had seldom returned to the normal level during several minutes of rest and was frequently higher during the second test than during the first. Strauss (90) has made use of measurements of the electrical potential of the skin, as a method of indicating the degree of fatigue. He held that the size of a potential drop during exercise is not a measure of fatigue, but that the rate of return to a normal potential after exercise is a measure of recovery from fatigue. Although attention is here called to a different measuring technique, we are left without recovery rates.

Although other investigations of recovery rates of one or the other of the three aspects of fatigue could be quoted from the literature, none has been made in which recovery in feeling-tone, organic state and output level were tested at parallel intervals following a continuous period of mental work.

The chief problem in such an undertaking is the selection of a bodily indicator which is relatively stable and easily obtainable on the one hand and yet sufficiently sensitive to express minimal changes in physiological reactivities. Recent experimental results suggest that with suitable attention to controls, palmar resistance changes may be taken as reliable indices of general excitation level. Unlike the biochemical techniques most frequently used to demonstrate physiological changes, the psychogalvanic technique is, in addition, available to the average psychologist. Skin resistance changes will be used therefore by this experimenter to detect organic change.

Space does not permit an adequate general discussion of the extensive and controversial literature concerning the psychogalvanic response. The reader is referred to the excellent summaries and reviews of Grünbaum (54), Prideaux (72), Woodrow (115), Landis and De Wick (59). Of these, the most recent and comprehensive is that of Landis and De Wick, published in 1929. A supplement by Landis (57) carries this up to 1932. However, as an orientation for the experimental study to follow, a brief account of the physiological mechanisms of the reflex, and of the previous applications of the psychogalvanic technique to the study of mental work will be worthwhile.

The Mechanisms of the Response

According to Prideaux, Landis and De Wick and others, Feré (36) was the first to point out in 1888 that an emotional reaction was accompanied by electrical changes in the human body, demonstrable by galvanometric deflections, when the resistance of the body to a weak electric current was being investigated. He noted that these changes were correlated with the alterations in volume of the limbs as shown by the plethysmograph, but reported that the galvanometric deflections had been insignificant in the normal persons he had experimented upon, and were only established for hysterical patients. Fere' continued this type of study until 1892 when he published his pathology of the emotions. Since Fere' utilized an outside source of electrical energy, the effect has come to be known as exosomatic in relation to the body or as the "Fere' phenomenon".

In the same year, 1888, Tarchanoff (91), a Russian physiologist, independently of Fere' worked on the electromotive changes in the body. He showed that the phenomenon was a normal one and occurred in all healthy individuals, when two non-polarizable electrodes attached to asymmetrical parts of the body were connected up with a galvanometer. This occurred especially during mental excitement, but was explained in terms of a "secretory theory" based upon the activity of the sweat glands. The current used by Tarchanoff has been named endosomatic in relation to the organism and the effect is often called "Tarchanoff phenomenon". Tarchanoff did not confine his situations to affective stimuli, since he used auditory, olfactory, and gustatory perceptions, ideational processes, and motor performance. Nevertheless, he did not rule out affective coloring in many of these cases.

The work of Fere' and Tarchanoff remained for several years unnoticed. It was not until E. K. Müller (59), an electrical engineer without any knowledge of the previous work, rediscovered Feré's phenomenon in 1904, and communicated his results to Veraguth (98) a psychiatrist and neurologist, that any methodical research was carried out. Veraguth considered that the phenomenon was physiologically induced through the activity of the sweat glands and that the mental aspect involved either a feeling of reality or compulsion, or an emotional setting, or both. He also gave the name psycho-physical-galvanic reflex to the phenomenon.

The theory that the reflex is due to muscular contractions was advanced by Nelson and Sidis in 1910 (84). It was short-lived, the evidence against it having been provided by Pieron (70), Fauville (35), and Wechsler (104). Pieron obtained no reflex when he applied electrodes to the leg of the cat from which the skin had been deliberately removed. Fauville repeated this experiment on the frog with the same negative effect. Wechsler applied electrodes to a portion of the body devoid of skin, the mucosa of the mouth of human subjects, and obtained no reflex. Thus, it was demonstrated that in order that the reflex may occur, the skin must intervene.

This view that the galvanic reflex was exclusively mediated by the skin, as well as limited to those portions that contain the sweat glands was, as mentioned, first suggested by Tarchanoff (1888). Approximately twenty investigators between 1888 and 1928 maintained that the sweat glands played some part in the response. Among these were Leva (62), Wechsler (104), Peterson and Jung (66), Waller (102), Prideaux (72), Richter (74), and Darrow (24). The experimentation of Richter and Darrow appears to be the most thorough and convincing. Since evidence provided by Darrow will be quoted to disprove the vasomotor throry, the burden of the proof of the sweat-gland theory will be placed on Richter. Richter points out that the electrical resistance of the skin is manifested in two ways: First, in a short transitory decrease in resistance which accompanies almost every emotional response; and second, in prolonged variations in resistance level occurring at different stages of mental activity and in varying moods. His observations apply to the prolonged variations. He found that this resistance decreased greatly when the sweat glands of the palms were stimulated to hyperactivity by sweat baths and pilocarpine injection. Resistance increased greatly when they were inhibited by atropinization. Similar results were obtained from monkeys when the sweat glands were paralyzed by transection of all nerves to the foot. The relationship between sweat gland activity and palmar resistance was further illustrated by the resistance curve during sleep. The palmar surface of the hand becomes very dry, while excessive moisture may appear on other regions of the body, particularly on the trunk where the sweat glands are scarce. Marked increased resistance accompanies the dry palms.

But it is important to note that in all of the above experiments relative moistness of the skin is significant merely as a criterion of sweat gland activity. For when the palms are sweating profusely and the resistance is low, careful cleaning and drying of the hands and reattachment of fresh electrodes doesn't raise the resistance. It remains at the previous low level.

Richter's results indicate too that palmar skin resistance is subject to nervous control. The transection of all nerves to either one fore foot or one hind foot in monkeys produced a great increase in resistance on the injured side simultaneously with the drying of the skin. The hypothesis that this control is mediated by the sympathetic nervous system was confirmed by a series of experiments in which the sympathetic fibers to the foot were severed and the somatic fibers left intact. Sympathectomy alone produced as large an increase in resistance as the transections of the entire nerve. Subsequent transections of the remaining somatic fibers produced no further change.

As was stated in the foregoing, the vasomotor theory of galvanic response was first advocated by Fere' in 1888. Among those who confirmed it were Sticker (89), Radecke (73), Uhlenbruck (97), Aveling and McDowell (5), and Wells (111). Veraguth advanced the first important opposition to the theory, his findings being substantiated by Pieron (70), Waller (102), Wechsler (104), Fauville (35), Darrow (24), and others.

According to Landis (57), "the work of Darrow in all probability settled this particular question". Darrow recorded simultaneously the vasoconstriction of the blood vessels of the skin at the point of attachment of the electrode, the temperature of the skin at this same point, the appearance of sweat as shown under magnification and the variation of the galvanic skin response. His work showed that this galvanic response appears simultaneously with the secretion of sweat and with alterations in the temperature of the skin. The secretion of sweat was photographed with micro-motion pictures, recording just how the eruptions of the sweat glands occur. The same method demonstrates that the vasoconstriction of the arteries or venules has no one-to-one relationship to the galvanic response. This vasoconstriction may precede, accompany, or follow the initial rise or the peak of the galvanic response. The galvanic response may also occur during vasodilation or when there is no vasomotor change. "The photographic records show these points so effectively as to bar further argument. Darrow has also shown that blood pressure and the galvanic skin response vary independently. The experiments of Bellingham, Langford-Smith and Martin show the same results as those of Darrow, concerning the secretion of sweat".

But, in the March 1941 Journal of Physiology, Darrow's evidence was challenged by the research of a group of English physiologists headed by Carmicheal (15). To quote:

> "In studying Darrow's records it is to be seen that his recording system must have been of low sensitivity, for no vaso-constriction was obtained with a deep breath. Further evidence against sweating as the sole cause of the response is its presence in a case of anhydrosis due to absence of sweat glands verified histologically as reported by Gilchrist (1927). Waller, however, has shown that the reflex can be obtained after administration of atropine. The validity of his results has been demonstrated although a reduction in the value of the response takes place after localized atropinization by means of ionotophoresis. This indicates the part played by vaso-motor activity in the production of the reflex".

Carmichael and his colleagues conclude, therefore, that the change in skin resistance to a given stimulus results from the activity of the sympathetic nervous system and is dependent upon two factors , sweating and vaso-motor activity.

The Autonomic Nervous System as a Factor in the Psychogalvanic Response

The part played by the autonomic nervous system in the production of the response has been frequently emphasized by many authors. Among the first investigators to provide experimental evidence were Schuberth and Schilf (79). These authors found that sectioning of the cord of a frog did not suppress the response but sectioning of the sympathetic ganglia did.

Richter's evidence (74) has already been given. It will be recalled that he used monkeys as subjects and found that resistance was not increased when the severing of all nerves to the foot followed sympathectomy.

The careful investigations of Darrow (30) were an important influence in establishing the sweat gland hypothesis. However, as we shall see in the next section, by 1937, Darrow (34) had modified his view with respect to limiting the response to sympathetic mediation.

The laboratory findings of O'Leary substantiate those of the earlier investigators. Cats whose cervical ganglion had been removed on one side only became the experimental preparation. This ganglion had been so removed that no sympathetic fibers whatever remained connected with one of the front paws, while the fibers to the other front paw remained undisturbed. Such an arrangement gave the experimenter an excellent means for comparing the resistance under identical conditions in all save the autonomic supply. Even the question of polarization and other physical factors which might enter could not destroy or interfere with the results which would be taken from a comparative point of view.

After the cats were accustomed to the unusual apparatus, readings were taken every two or three minutes for thirty minutes. It was found that the resistance fluctuated considerably on the intact side while the resistance of the operated side remained absolutely the same. In spite of the cat's continued restlessness, the operated paw showed not the slightest change in resistance. Marked emotional states produced by pinching and twisting the tail of the cat resulted in wide fluctuations in resistance in the intact paw, but no change whatever in the operated paw. In all cats similarly prepared, the sympathectomized side showed no change at all in resistance.

As mentioned in the foregoing section, Carmichael (15) and his colleagues provide evidence from which they conclude that the change in skin resistance to a given stimulus results from the activity of the sympathetic nervous system.

Probable Combined Sympathetic and Parasympathetic Excitation of the Sweat Glands

Darrow (24, p. 650) makes the statement that "in many cases excitation of centers in the brain produces galvanic response attended by parasympathetic activity in structures other than the sweat glands. "This", he says, "would not readily occur if the galvanic activity must invariably be mediated by excitation of the sympathetic chain. It would not occur because in the first place the sympathetic chain is notoriously given to the production of mass effect. It would not occur because in the second place a generalized sympathetic activity sufficient to cause an appreciable galvanic response would tend to neutralize or even overshadow parasympathetic influence on other bodily structures".

The hypothesis is tentatively set forth by Darrow (24, p. 659) that impulses to the sweat glands may fall into three general classes: "First, those from the central nervous system which pass through or avoid the sympathetic chain (these may be accompanied by parasympathetic effects on other structures); second, those which reach the sweat glands as a consequence of generalized excitation of the sympathetic chain (these will be accompanied by sympathetic effects in other bodily structures); and third, those which represent a combination in varying proportions of types 1 and 2 (these may be attended by variable or by zero effects on other bodily structures)".

A further fact regarding the peripheral mechanism of sweating is that the distribution of the peripheral sweat fibers corresponds almost exactly with that of the fibers for pain, somewhat less closely with those of touch, and relatively poorly with those for heat and cold. Jenkins and Darrow have found a corresponding spatial distribution and temporal course of loss of pin prick sensitivity, elevations of skin resistance, and disappearance of microscopically observed sweat following procaine block of the ulnar or median nerves.

Centers Mediating the Response

The view of the earlier investigators who worked chiefly on human beings was that the galvanic response was conditioned by the functioning of the higher centers; hence, for instance, the term psychic in Veraguth's definition of the response. It was Gildemeister (47) who first definitely rejected this view. After Schwartz' (81) experiments on the direct illicitation of the response by stimulation of the sciatic nerve of the frog, Gildemeister argued that the whole phenomenon was of a purely reflex nature, in no way dependent upon the higher processes. He suggested that the term neurogalvanic reflex replace the term psychogalvanic.

Some of the more significant experiments made for the purpose of determining the mediating centers are given brief attention. Veraguth (98) found that in an anesthetized cat, the response was entirely suppressed. On the other hand, Schuberth and Schilf (79) report that they obtained the galvanic response in the frog after both hemispheres as well as the optic lobes had been removed.

Determination of mediating centers as regards human beings is quite difficult. Higher centers cannot be removed surgically. As far as this author has been able to determine, nobody has attempted to obtain the response in a patient under anesthesia. Richter and Wechsler did do the next best thing. Both obtained the response from sleeping subjects. This evidence may be interpreted as lending support to the view that cerebral activity is not indispensable to the response.

The most recent evidence has again been provided by Darrow (24). According to Darrow, there is evidence that the autonomic nervous system as well as the innervation of the skeletal musculature finds representation within the cerebral cortex. Proceeding from this premise, he identified the cortical and midbrain mechanisms which control the galvanic skin response.

Cortical Control of the Galvanic Skin Response

In reviewing the evidence Darrow (24) calls attention to production of sweating in the footpads of the cat and the hands of the monkey by stimulation of the pre-motor cortex. Becterev (24), Winkler (24), Langworthy and Richter (24), and Spiegel and Hunsicker (1936) found this to be true with cats. Fulton, Kennard, Watts and Viets, on the basis of their studies maintain that, there is little question but that in anthropoids the cortical region for this autonomic activity is in the premotor cortex.

An electrical stimulus to the premotor area produces widespread movements generally first apparent in the more distal portions of the extremeties. Various vasomotor and secretory changes which may be regarded as facilitating manipulative activity occur with these movements. Such investigators as Freeman, Kennedy and others have reported patients with a deficit in the gray matter of the premotor cortex as unable voluntarily to relax the grip of an object in the hand contralateral to the lesion. This "forced grasping" was produced experimentally by extirpation of the premotor cortex in the monkey. The condition of "forced grasping" is attended for a period of about ten days by profuse palmar sweating and by vasomotor disturbances of the extremity.

Darrow's results from simultaneous records of galvanic changes in the two hands of normal subjects indicate that when a normal person with an intact nervous system lies on one side, the palmar secretory activity tends to be reduced on the palm of the downward hand. Rabiner found the grasping response exaggerated in emotionally disturbed patients. With the sense of insecurity typical of chronic anxiety and certain states of depression, the palmar secretory activity is also frequently excessive.

The Psychogalvanic Response as a Bodily Indicator

It may be recalled that at the beginning of this discussion, fatigue was arbitrarily defined as a measurable decrement in output, subjective feeling-tone and organic state. The necessity for a relatively stable, easily obtainable and sufficiently sensitive indicator of physiological changes was further pointed out and experimental evidence for skin resistance changes as such a measure was promised.

Freeman and Giffin (43) conducted an investigation designed to compare under identical conditions, the efficacy of two bodily indicators, skin resistance and oxygen consumption. Fifty adult males served as subjects. Metabolism and palmar skin resistance under standard basal conditions were simultaneously recorded. In some cases specific stimulation effects resulting from electric shock and muscular tension were superposed. The results indicate: First, palmar resistance changes were not only more stable in test-immediate-retest situations, but also more reliable than the metabolic measures when the tests were some days apart; second, a low rate of oxygen consumption accompanies a high palmar skin resistance; third, metabolism, as measured by oxygen consumption at least, is relatively insensitive to stimulation effects superposed on the basal state. In the interpretation of their results, the investigators emphasize that changes in palmar skin resistance represent perhaps less extensive increments in total bodily activity than records of oxygen consumption, but that important increments in energy mobilization would often be masked in the records of total oxygen consumption.

Psychological Correlates of the Psychogalvanic Response

Many observations but few careful experiments have been made in regard to the relation of psychogalvanic responses to mental work. Tarchanoff (91) found that multiplication requiring effort produced the response. Veraguth (98) found that silent reading of dry scientific reports produced little change, compared to reading for the same length of time a patriotic speech.

One of the most detailed experiments with mental work and the galvanic response was carried out by Daniel Starch (87) with ten subjects. He recorded the general curves that occurred during periods of physical and mental work. The chief results may be summarized as follows:

1. A typical passive curve (when the subject is doing nothing) runs along by small zigzags on the same general level.

2. During mental work (fixating a cross and trying to observe all of a row of six letters twelve centimeters to the right of this) there was a fall in resistance. The fall was usually most marked at the beginning of the mental work. The work period was very brief as the subject was instructed to stop when he felt discomfort.

3. The fall in the curves of resistance was generally less for the mental work than for the muscular work (rhythmic lifting of the right knee). Starch (87, p. 36) concluded that "those types of mental processes which are accompanied by the most distinct and widespread physiological changes produce the largest deflections, such as muscular activity in lifting knee, strong emotions accompanied by start or shock, halting and quickening of respiration, muscular tension, etc."

Affective Tone and Galvanic Deflections during Mental Work

The determination of the part played by affective tone in producing psychogalvanic deflections during mental work was attempted by Radecki (73) at the University of Geneva. He used mental multiplication of two-place numbers. In most cases the time interval between stimulus and response was much longer than the latent period for the galvanic skin response. Thus Radecki assumed that the galvanic skin response is absolutely independent of the intellectual work itself and that it depends wholly on a process of emotional excitement, resulting from meeting a difficulty in the Problem.

Continuing Radecki's work at Geneva, Abramowski (2) reported: First, that the deflection occurred at the beginning of mathematical calculation; and second, that usually the subjects good in arithmetic gave no deflections whatever. Phillip and Menzerath also concluded, "that it is not so much the relative difficulty of the calculation that matters as the emotion accompanying it, for good mathematicians manifested the response only upon making a mistake".

Sears' (82) subjects were required to find orally the sums of addition examples, while the amplitude of the galvanic deflections occurring during this mental work was recorded. Examples of varying complexity were presented in different sequences with no time limit. Examples of approximately equal complexity were presented in various sequences with a limited time allowance.

Sears found that the amplitude of psychogalvanic reaction is consistently related to changes in speed and difficulty of the type of mental work which he employed. He suggests from his results that the galvanic skin response can no longer be considered as measuring the effect of conation or emotion on mental output but must be most satisfactorily interpreted as an indicator of "increased sympathetic activity or of increased feeling-tension".

Relation of Acts of Choice and Judgment to the Galvanic Skin Response

The conclusions of the very carefully conducted experiments of Wells and Stevanovic may be included under this caption. Wells had subjects make choice between liquid tastes of varying hedonic quality, some pleasant, some unpleasant, and some neutral, but all odorless, colorless, and labelled only with nonsense syllables. She found that in all five cases the average percentage drop in resistance was greater in the case of difficult choices than for the average of all choices. Stevanovic's task consisted of completion sentences composed of a series of irregular figures of the "ink spot" type, given nonsense names. Stevanovic explained the negligible relationship between difficulty and galvanic skin response deflections by saying, "when the subject comes to make his judgment, the mere apprehension that the stimulus has to do with a judgment of this kind arouses his alertness". Both Wells and Stevanovic (88), then, consider that conation rather than emotion or affective tone is the essential conscious correlate of galvanic skin response.

R. B. Cattell (16) who used a wide variety of stimuli which he classified under three main headings, as evoking conation, feeling, or cognition has concluded that, "the reflex is more nearly proportional to the conative elements in any experience than to the affective or cognitive."

Influence of Attitudes on the Galvanic Skin Response

In an experiment of T. M. Abel (1), 20 problems of the following type were given to each of six subjects:

(a) Analogies, e.g., $\dfrac{\text{Volcano}}{\text{Igneous}} : \dfrac{\text{Earthquake}}{\text{Granite}}$

(B) Statements of fact, e.g., "Oxygen is heavier than ozone."

Abel found that "the subject's attempt to solve or at least to comprehend the problem presented was frequently, but not always, accompanied by a deflection of the galvanometer". She believes that the electrical changes accompany certain reportable attitudes ("Bewusstseinslagen") which represent "sudden, decided and momentary checks" in the solution of the problem. These she thinks can hardly be classed definitely as either emotional or conative.

Incidence of Galvanic Skin Reactions during Continuous Mental Work

Wechsler mentions a series of experiments in which he tried to separate the effects of mental effort from the effects of emotion, so far as these are related to the galvanic response. He tested his subjects with mental arithmetic examples of the following type: 7, plus 3, plus 6, divided by 2, minus 3, plus 8, minus 5, times 4, minus 8, divided by 4 equals? He notes that this type of problem is of much longer duration than those previously employed.

It was found by Wechsler that with such examples the deflection occurred even before the problem was begun, when the subject had merely been given a signal. Only in a few cases did any deflections occur during the solution - these when the subject met with some difficulty.

In Wechsler's opinion these observations add further evidence "that it is the accompanying affective tone of mental effort .... that provokes the galvanic reaction".

Tension as an Explanation of Galvanic Deflections

Both mental and physical work were investigated by M. M. White (114) who took records of electrical changes occurring during work with the dynamometer, and during work with multiplication problems. These were compared with the changes in electrical resistance during relaxation and sleep. It was concluded that electrical resistance is higher in relaxation than in tension, and that the tension during mental work causes a greater decrease in resistance than general or local contracture.

Landis and Hunt (57) presented a group of subjects, representing a diversity of academic influences, with thirty stimuli chosen to represent ten supposedly different psychological categories. The subjects were requested to note their conscious experience accompanying a stimulus. Resistance changes were recorded during responses to stimuli.

The outstanding score of "tension" was one of the most interesting of the results of the subjective classification. All of the reports of tension were accompanied by galvanic deflections, and the average amount of the deflections was greater than that for any other category of reported conscious content. This is particularly interesting in view of Sear's conclusion (see foregoing) that "perhaps tension or feeling-tension would best fit cases of high psychogalvanic reactivity".

Fatigue in Mental Work and the Galvanic Skin Response

One of the first observations made by Tarchanoff (91) regarding the galvanic response is that physical fatigue tends to diminish it (increased resistance). Bose, as a result of experiments on plant and animal tissue, declares that, in general, "conductivity of tissue is impaired by fatigue". Wechsler makes the same claim.

Wechsler (104) also investigated the effect of mental work on the response. Using the Binet-Simon intelligence examination, he took the body resistance immediately before and after the examination. He observed a significant increase in resistance after the examination for two out of three of his subjects.

Ruckmick (78) performed an experiment on himself. He solved a set of twenty problems in mental multiplication of the order of 54 X 17, while painful and unpleasant stimuli were being presented as distractions. His introspective records gave qualitative pictures of "extreme bodily fatigue and mental lassitude". Photographs of facial expression revealed the appearance of a sort of all-in-attitude. However, the exhaustion showed no mental effect about an hour after the experimental series. Ruckmick concluded that, "It is evident from the fairly consistent results, that we must regard the phenomena of fatigue as of the same direction as that which characterizes both affective and motor responses, namely, a decrease in resistance or an increase in counterpotentials from the sweat glands". He advanced the hypothesis that "perhaps fatigue truly represents a retardation of the activity of the higher cerebral centers and a relapse to the control of the lower centers like the hypothalamus. In that event it might be plausible to suppose the same kind of activity to remain that obtains in the affective area through connections with the sweat glands and the autonomic system".

One of the most carefully conducted experiments in this category is that of Geldreich (45) who reported skin conductance changes during mental fatigue. The mental task used was continuous manual responding to serial presentation of colors. By practicing the subjects until they reached an average rate of about ninety colors per minute, fatigue decrements in the work curves were not masked by practice increments. The experimental condition consisted of fifty-five minutes of mental work preceded and followed by ten minutes of rest.

Geldreich's results show "an apparent concommittance in increase in level of skin resistance as mental work efficiency decreases". During the prework rest period of ten minutes there is a gradual increase in resistance which is interrupted by a radical decrease in the level of resistance for the first two or three minutes of mental work. This drop in resistance is accompanied by an initial high level of work. From this point on, there is a gradual increase in the level of resistance, though interrupted by numerous galvanic skin responses. These are not consistently present during the control period of fifty-five minutes of relaxation, not during the ten-minute pre- and post-work rests.

Geldreich interpreted his results as "fitting the established relationship between changes in bodily tension and changes in skin conductance". That is to say, he identifies steady reduction in energy in continuous mental work with decreased tension and an increase in resistance, for, the more apprehensive and attentive a person is, the greater is the tension and the lower the level of palmar skin resistance. The periodic changes in efficiency in mental work are associated with periodic changes in attention and apprehension, these same changes resulting in galvanic skin responses. The results and the interpretation in this study follow closely the observations made by Sears which have just been described.

Purpose of the Experiment

The purpose of this experiment was to determine the form of the curve of recovery from mental fatigue. In view of the three approaches to the study of fatigue, there were, in reality, three objectives: First, the determination of the curve of recovery for mental work output; second, that for the concurrent skin resistance changes; and third, the curve of recovery for subjective feeling-tone.

In the graphical representation of recovery for mental work output, minutes of rest elapsing after cessation of continuous work are represented on the abscissa and relative increments in output or recovery ratios on the ordinate. The method employed in arriving at these recovery ratios is explained in detail in the subsequent section. Having plotted the empirical curve indicating the relationship between the recovery ratios and minutes of rest, the experiment was further designed to determine the mathematical evaluation of the curve. In other words, the regression equation for the theoretical curve of best fit was sought.

The second objective, that of determining the physiological changes concomitant with the period of mental work and the subsequent recovery period was accomplished by plotting the curve of skin resistance changes.

The curve of recovery for subjective feeling-tone was based on rating scale values.

Subjects and Conditions of the Experiment

Six groups of twenty-five college men and women each were used for the experiment. The groups were about equally divided on the basis of sex. Intelligence quotients for individuals comprising the groups were based on scores obtained on the Otis Mental Test. Table I, page 29, presents the average intelligence quotient of each group. The means and standard deviations shown in the table are almost identical, showing how closely the matching was done.

During the period of continuous work, influencing factors were held as constant as possible for all groups. But rest periods varying in length were inserted after work. Hence, Condition I, should identify the group permitted a two-minute rest; Condition II, the group with the three-minute rest; Condition III, the five-minute; Condition IV, the seven-minute; Condition V, the ten-minute; and Condition VI, the twenty-minute.

Preliminary Procedure

Introductory Statement - Before the experiment could be undertaken, it was necessary to find some manner of producing fatigue and of measuring the three phases of recovery.

Characteristics of the Fatigue-Producing Task - It has been demonstrated by such investigators as Bills and Robinson that the amount of decrement in mental work varies with the nature and difficulty of the task. Where tasks of varying degrees of homogeneity were used, it was found that highly homogeneous tasks produce more rapid decrements than

TABLE I

AVERAGE INTELLIGENCE QUOTIENTS FOR THE SIX EXPERIMENTAL GROUPS

Condition or Group	Averages	Standard Deviations	Standard Errors
I - 2 Minutes	124.6	5.29	1.06
II - 3 Minutes	123.3	5.18	1.03
III - 5 Minutes	124.4	5.35	1.07
IV - 7 Minutes	124.1	5.47	1.09
V - 10 Minutes	123.4	5.47	1.09
VI - 20 Minutes	124.2	4.97	0.99

do varied or heterogeneous tasks. The law of homogeneity is that: the more homogeneous the task, the greater the decrement. Closely related to the principle of homogeneity is that of continuity. The more continuous the task, i.e., the more rapidly the succession of stimulations follows one another, the greater the decrement. Also, mental work involving the operation of firmly established habit systems suffers less fatigue decrement than work involving unpracticed habits. Homogeneity, continuity, and stage of practice, then, are some of the main characteristics of the mental work task which determine the amount of fatigue decrement.

What types of task incorporate these principles? Mental addition and multiplication, cancellation, color-naming, code substitution and completion tests predominate in experimental literature. However, figure analogies involving reasoning by analogy were recently satisfactorily employed by Newburger in an investigation of difficulty and homogeneity as factors in producing fatigue. He introduced the factor of homogeneity by repeatedly rearranging a single problem situation and by varying the order of its correct response. Thus, a marked degree of similarity resulted without repetition of identical problems. In addition, the relative unfamiliarity of this material to most subjects adapted it to control of initial stage of practice. It lends itself also to objective recording.

Convinced of the adequacy of Newburger's material as a fatigue-producing task, this experimentor adapted it for use in the present investigation. But, four times as many items were required due to the extended work period. Adaptation, thus, took the form of providing 324 additional combinations. See Appendix A for the final form of 432 analogies.

<u>Method of Measuring Objective Recovery</u> - It has already been pointed out that objective fatigue is identified with decrement in speed and quality of output and, conversely, that objective recovery is identified with increment in speed and quality of output. In addition to the variation in these two factors resulting from continuous work, a very significant change takes place in the character of the performance itself. The performance is not continuous (even though the worker tries to make it so) but is interspersed with short pauses or blocks which are as long as two or more average response times. These blocks increase in frequency and length throughout the work period. The increase which occurs in the length and frequency of blocks gives the worker enough rest to compensate for some of the fatigue which would otherwise develop. Due to this recuperative function the blocks must be included as objective recovery criteria.

Just how can recovery be quantitatively measured in terms of these criteria? What specific technique must be employed?

Interpretation of the specific technique employed is dependent upon the understanding of two observable general trends in curves of continuous work. One of these is toward a drop in performance, the other toward a rise. The drop is attributed to fatigue. The rise, if representing a permanent change in capacity, is a function of practice. Now practice may, thus, be defined as that improvement which persists. Since it is almost never possible to bring the subject to a condition of 100 per cent practice in the task before obtaining the work curve, the work curve practically always contains within it both the effects of the practice and the fatigue factors. Fatigue has been defined as that condition of lowered efficiency which is removable by rest. Hence, it can be assumed that a day's rest will be more than enough to remove all of a normal fatigue decrement. That is to say, all efficiency lost will have been regained. Recovery will have been complete.

All other things being equal a subject should begin work after a day's rest at the same level at which he started on the previous day. Now, if instead, he begins at a higher level than previously it must be assumed that a practice effect has carried over to the following day. Actually, this practice effect was present at the end of the first day's work and, if not evident in the curve, was masked by the fatigue effect. Conversely, the fatigue decrement may be obscured by the practice increment.

It follows from the foregoing assumption that the increment in performance level on the following day over the final level on the preceding day represents complete recovery or 100 per cent recovery. In terms of arithmetical process, performance score on the second day minus performance score at the end of the continuous work period the previous day equals 100 per cent recovery. In the present investigation five minutes of performance the second day were compared with the last five minutes of continuous work on the previous day.

The present study is concerned with the amount of recovery occuring during six relatively brief rest periods inserted immediately after cessation of work. Amount of recovery during each of these periods can be calculated by comparing the performance immediately following rest with that immediately preceding rest. More specifically, the performance score for five minutes of work immediately after rest minus the performance score for five minutes of work immediately preceding rest may be interpreted as a quantitative measure of the recovery of efficiency during rest. In other words, this method yields the absolute amount of recovery for each of the six rest periods.

This question now naturally arises: What proportion of the quantitative value representing 100 per cent recovery is the amount of recovery that occurred during each of the six brief rest periods? This relationship of the whole to its parts may be expressed in the formula

$$\text{Percentage of Recovery} = \frac{S_2 - S_1}{S_3 - S_1}$$

in which S_2 symbolizes the output score for the five minutes of work immediately after rest; S_1, the output score for the last five minutes immediately preceding rest and S_3, the output score for the five minutes of work the following day.

By applying the formula, a recovery percentage or ratio was computed for each of the 25 subjects for each of the 6 variable rest periods. To illustrate: Subject A worked or attempted 23 analogies during the last five minutes of the continuous work period, 30 immediately after a five minute rest and 35 during five minutes of work the following day. Substituting these values in the formula, $\frac{S_2 - S_1}{S_3 - S_1}$ yields the compound fraction $\frac{30 - 23}{35 - 25} = \frac{7}{10}$ or 70 per cent. Subject A then recovered 70 per cent of the efficiency lost during thirty minutes of continuous work by resting for five minutes. By averaging the twenty-five individual recovery ratios, one recovery ratio for a given group was obtained. In this manner a recovery ratio for each of the six rest periods was obtained. It will be recalled that the first experimental objective was to determine the shape of the curve representing the relationship between recovery ratios and minutes of rest. In this graphical representation recovery ratios were to be designated on the ordinate and minutes of rest on the abscissa.

The foregoing method with appropriate modifications was used to determine recovery ratios in terms of problems worked correctly and in terms of blocking.

Measurement of Skin Resistance - As was stated in the foregoing, changes in skin resistance were expected to reflect changes in physiological processes which operated concomitantly with the changes in mental function. The mechanisms on which the skin resistance changes depend and their physiological and psychological correlates have been reviewed. Hence, there remains for consideration the method of measuring these changes in skin resistance. The essential features for measuring them consists of placing the body in circuit with an extremely weak direct electric current which is relayed through a galvanometer. Stimulating the subject, while in this circuit, produces galvanometric deflections. The magnitude of the galvanometric deflections will depend upon (1) the sensitivity of the galvanometer, (2) the magnitude of the current employed in the circuit, (3) the body resistance of the subject, and finally (4) the intensity of the physiological reaction produced by the psychic excitation.

Of these four factors the last is the variable we wish to measure and compare, hence, the other three must be kept constant during any given experiment or series of experiments. The measuring instrument, or galvanometer employed, therefore, must be equipped with necessary controls to meet these requirements. Darrow has developed a type of resistance box, known as the "Behavior Research Resistance Box", which meets these requirements just discussed, and gives in addition a continuous quantitative record of both resistance level and resistance changes in the subject. The important feature of this apparatus is that the resistance in three arms of the Wheatstone bridge is kept constant, the only changes occuring in the fourth or subject's arm of the bridge.

Since, the Wechsler psychogalvanograph which was available for use in the present experiment lacked the above mentioned features, it was necessary to make extensive modifications in it to conform to the Darrow circuit.

Comparison of the wiring diagrams of the two instruments reveals the essential differences between the two bridges. The diagram for the circuit of Darrow's "Behavior Resistance Box" is found in Figure 1 on page 36. That for the Wechsler "Psychogalvanograph" is found in Figure 2 on page 37. Wechsler shows two variable arms as compared with Darrow's one variable arm.

Because of the rather striking difference in the Wechsler circuit it was deemed advisable to try it in a preliminary investigation. Details of both the procedure and results of this pre-ex-perimental study may be found in Appendix B.

The evidence demonstrates that, with the Wechsler circuit as it stood, it was impossible to secure reliable scale calibrations per 1000

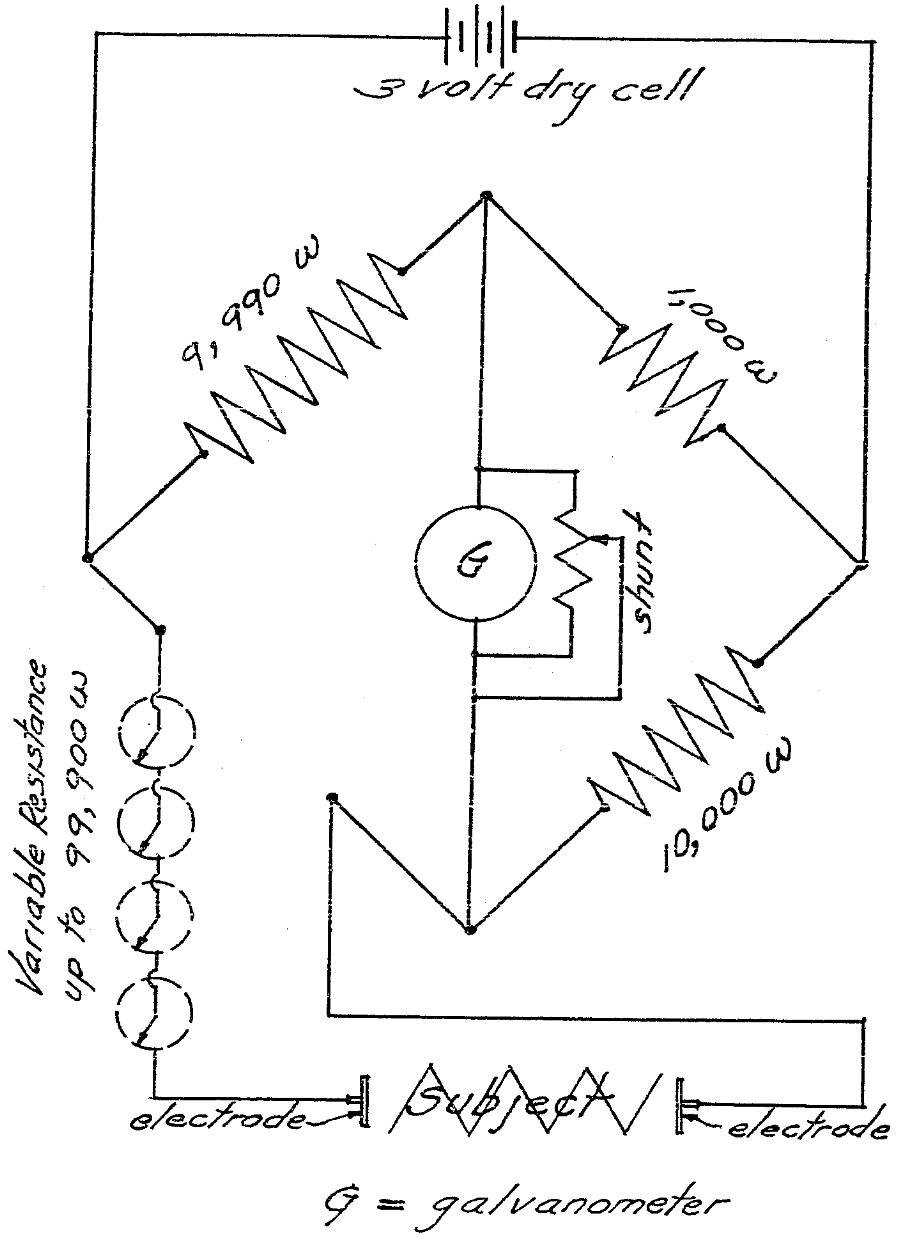
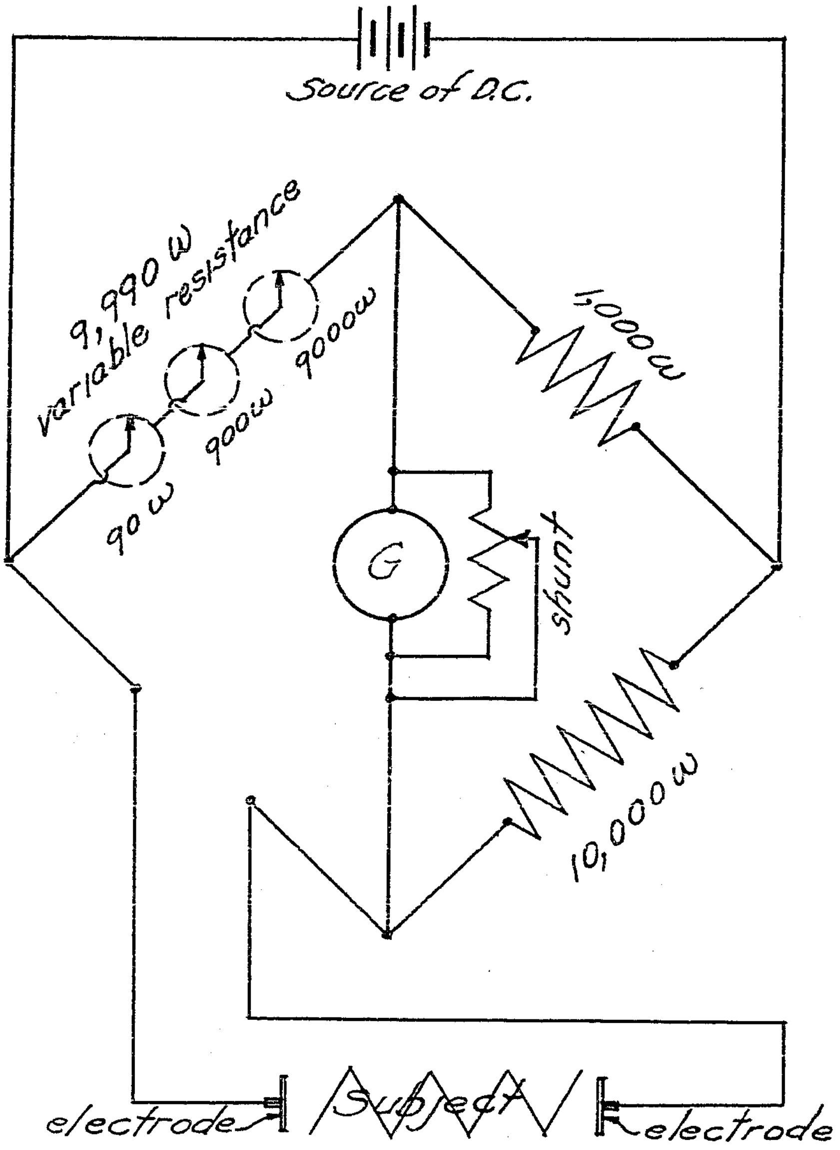


FIG. 1
A simplified diagram of the Behavior Research Resistance Box circuit as used



G = galvanometer

FIG. 2
A simplified circuit diagram of
the Wechsler Psychogalvanograph

ohms resistance for a series of workable basic resistances. This was the case when sensitivity was held constant. It was also the case when calibrations were held constant and sensitivity varied. Now, resistance changes based on unstable quantitative measuring units would not only be valueless in themselves, but would tend to cast doubt on results obtained from any more accurate measure which may simultaneously be made. In addition to the foregoing disadvantages, manipulating the sensitivity shunt fast enough to keep pace with the rapid changes in human resistance levels required more attention than one experimenter could give in this otherwise complex experimental situation.

The Wechsler circuit was, therefore, converted into the Darrow type of circuit. In the fourth or subject's arm of the Wechsler bridge a 99900 ohm resistance box was substituted and the actual resistance in the third arm of the bridge was held constant at 9990 ohms. Darrow has shown in his apparatus that when a large amount of resistance is thrown into the circuit in series with the subject, the current through the subject can be kept much more constant from time to time. Due to the increased resistance introduced into the Wechsler circuit, the original 1-1/2 volt dry cell was replaced by a 3 volt dry cell.

With this new circuit high sensitivity could be utilized. To be exact, sufficiently refined scale calibrations for both the relatively low and relatively high basic resistances were now made at a sensitivity of 40. With the original circuit, sensitivities as low as 4 and 8 produced unsatisfactory results. The table of calibrations made with the adapted circuit and used in the experiment proper to convert scale deflections into resistance changes is found on page 157 of Appendix B.

The type of electrodes used in the measurement of galvanic response has been the subject for as much controversy as has been the circuit itself. Many devices have been proposed. Tarchanoff used non-polarizable electrodes made of clay. Hypodermic needles made of platinum were used by Sidis & Nelson. Zinc, zinc sulphate, nickel-plated brass, copper, kaolin, and zinc oxide have all been employed, either with or without a covering of chamois skin. The following prerequisites are essential:

1. The area of contact with the skin must be kept constant. Any variation in this area will change the registration of the electrical output.

2. The area of contact must be large enough to eliminate the possibility of electric shock. Some individuals are very sensitive to feeble currents.

3. The pressure on the skin must be constant. If it is not sufficient to insure maximal conductivity, extraneous artificial resistance will be introduced. However, if it is excessive, affective reactions due to the discomfort may occur.

4. The degree of moisture between the electrode and the skin must be kept constant. Variation in the degree of moisture would change the registration of the electrical properties to be measured.

5. The electrodes themselves should not generate any variable electrical properties, such as polarization. These would distort registration of such changes assignable to the body itself.

During the trial of the Wechsler psychogalvanograph, it was observed that the electrodes on certain types of hands gave neither constant pressure, nor constant contact. On subjects having bony hands the mark left on the back of the hand after removal of the electrode showed very plainly the fact that a full contact had not been made. On some subjects having sharply arched hands this lack of contact toward each side of the hand could even be observed with the electrode in place with as much pressure as the subject would allow. In the case of one subject having this type of hand together with a very low basic resistance allowing a high current flow, the resulting current intensity was sufficient to break the skin and cause some irritation.

For the above reasons the writer had constructed a pair of electrodes similar to those listed in the Stoelting supplement (electrodes #24217A). These electrodes were designed by Darrow. Geldreich states that he used the electrodes in his investigations and recommends them highly.

The inactive electrode is a clean piece of zinc plate about 2 inches square and curved to fit the volar part of the arm. To this zinc plate at its center is soldered the bottom end of a binding post. A rubber strap, through which the binding post passes is used to fasten the electrode on the arm. This arrangement if properly adjusted to the arm insures constant contact area.

The active electrode consists of a bathtub stopper into the cavity of which is inserted a zinc plate about one inch in diameter. To the center of this plate is soldered the bottom end of a binding post which passes through a hole in the top of the stopper. The binding post also passes through a hole in the center of a small four-legged table arrangement. The top of this table is made of a two-inch square of plastic sheet. Its legs are each about an inch long and are fitted on the bottom with rubber cushions. These cushions flatten down the palmar area and tend to minimize palmar creasing. A small compression spring is fitted over the binding post above the stopper and below the table top. This table electrode is buckled to the palm of the hand with two rubber straps which acting against the spring maintain constant pressure. For pictures of both electrodes see page 42 Plate 2 .

A physiological solution of zinc sulphate was used as the electrolyte. Filter paper discs soaked with a mixture of 60 per cent zinc sulphate solution and 40 per cent glycerin were placed directly in contact with the skin on the arm and the palm. The glycerin prevents the zinc sulphate solution from drying. The inactive electrode was then fastened down on the arm directly over the filter paper. Fitted into the cavity of the stopper of the active electrode was a small cylinder of sponge rubber about one inch long and one inch in diameter. This cylinder had been thoroughly pierced lengthwise and saturated with a kaolin paste made with zinc sulphate solution. The electrode was then strapped down over the filter paper in the palm.

The technique thus far described was intended to produce relatively constant moisture, constant contact area and constant pressure. Polarization effect only remains for consideration according to the previous outline of the prerequisites for adequate electrodes. This test was made through the courtesy of the Physics Department. When the prepared electrodes were bound face to face with the filter paper between and placed in series with a galvanometer, the resulting EMF was found to be .01176 or 1/3 of 1 per cent of the three volt dry cell. This was

PLATE I

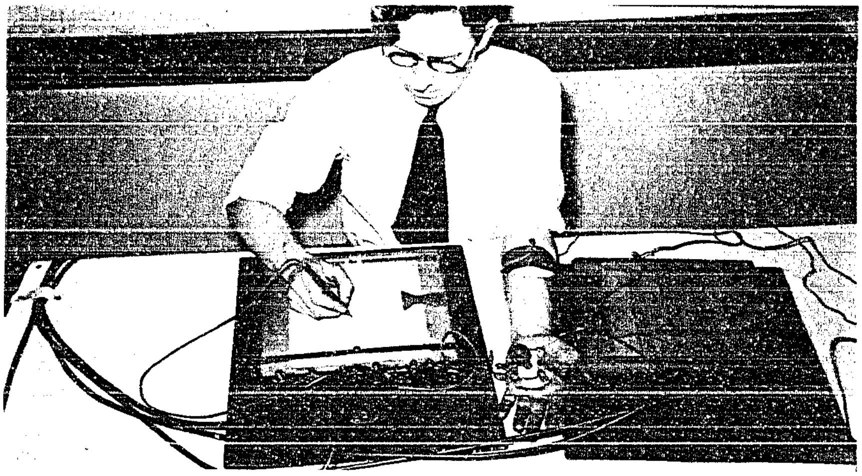


PLATE 2

thought too small to be significant.

Measurement of Subjective Feeling-Tone - As has already been stated, like all subjective variables, subjective fatigue must be measured by means of a rating scale based on the subject's introspective report. The feeling-tone scales used in this investigation are found on page of Appendix A. Four cards, with a feeling-tone scale drawn on each are shown.

An individual's judgment of his feelings toward a specific task at a particular moment depends upon comparison with the memory of his feelings toward other tasks done in the past. Then too, at different times an individual may feel more like beginning a task than he does at others. The four scales were constructed with these two principles in mind. The subject who felt more like working on the experimental task than any he had ever done selected Card No. 1, at point 10 on the scale; he who felt more like working than usual, Card No. 2, at point 9 on the scale; as well as usual Card No. 3, at point 8 on the scale; and less than usual Card 4, at point 7.

In addition to provision for designation of feeling-tone at the beginning of the task, the scale was planned for use at regular intervals during work, at the beginning of the work period following rest and at the beginning of the work period the next day. From these values a curve was plotted. The units on the horizental axis represented minutes of rest and those on the vertical axis improvement in feeling-tone.

Apparatus and Procedure

The Wechsler psychogalvanograph adapted to the Darrow circuit, the two electrodes and two punch boards connected to a chronograph constituted the essential pieces of apparatus. The galvanometer circuit and the electrodes were described in the preceding section. The punch boards only remain for consideration. Each punch board was constructed to accommodate one sheet of analogies. A sheet of analogies contained three rows of thirty-six problems. Each problem was composed of seven symbols, four of which represented possible solutions. The punch board was arranged to allow an opening beneath each of the four possible responses. The base of each opening was composed of copper. When the subject punched through a response on the paper with s stylus, he completed an electric circuit and caused a record of the movement to be made upon a strip of paraffined paper moving through a motor driven chronograph. By this method the time required for the solution of each problem was indicated on the tape. The subject at the same time indicated his choice of solution. On page 42 is shown a picture of the arrangement of the apparatus during the experiment.

Two punch boards will be noticed in the picture. During the preliminary experiment with the galvanometer, three of the ten subjects during a 15 minute work period completed more than one sheet of 108 analogies. Thirty minutes of continuous work were allowed each subject during the experiment proper. It could be expected when the possibility of practice effect was taken into account, that some subjects would complete at least three sheets of problems. It will be recalled that one board would accommodate only one sheet. To avoid gaps in a subject's continuous work period, it was necessary to shift quickly from board to board as each sheet was completed.

The subject's chair was equipped with two comfortable arms and was well padded with a rubber cushion. Since the electrodes were attached to the left arm, it was necessary that it be resting in the same position throughout the experiment. During the recuperation periods, the subject was expected to relax the entire body as completely as possible.

Experimental Procedure without Galvanometric Measurement

Introductory Remarks - Variation in the length of the rest period, it will be recalled, was the sole differentiating feature between the six experimental groups. All other influencing factors were held as constant as possible from group to group. There was, however, a division within each group itself. That is to say, skin resistance changes were recorded for eight of the subjects, but no such recordings were made for the remaining seventeen. For these remaining seventeen subjects, the experimental procedure included no galvanometric measurements. It consisted of: First, An instruction period; second, thirty minutes of continuous solving of analogies; third, a rest period; fourth, five minutes more of work with analogies; and fifth, five minutes of work with analogies the following day. The details of these five phases of procedure will be considered first.

Motivation of the Subject - Since the measurement of recovery from fatigue was the purpose of this study, it was very essential that the subject's performance during the work period show the maximal fatigue decrement. It was feared that, if the subjects realized that they were deliberately being fatigued, their performance might be inhibited. Hence, it was necessary to give them a plausible reason or motive for putting forth their maximal effort. Therefore, the experiment was described to them as a study in efficiency and they were urged to work as fast as possible consistent with accuracy. It was pointed out that the significance of the final experimental results depended upon their absolute cooperation. This was so essential that a ten-dollar cash award would be given to the subject making the highest efficiency score. There would be daily posting of scores in the laboratory to keep the group informed with respect to changes in the subjects' ranks. Scores were not posted if the subject desired it.

Reading of Instructions - At this point the subject read the instructions for working the analogies (See Appendix A - page 132) and then actually solved some with the aid of the experimenter. The subject next read instructions for marking the feeling-tone scales (See Appendix A - page 136). He selected his feeling-tone card which was posted on a small easel in full view for his future reference, and conveniently placed for the experimenter's checking. The subject was told to tap the binding post with the stylus twice when he heard the signal "Go" and to work until he heard the signal "Stop". Contacting the binding post caused a record to be made on the chronograoh tape of the time at which work was initiated. While waiting for the "Go" signal he was reminded that he was to work as fast as he could consistent with accuracy and that ten dollars would be his if he made the highest score.

The Continuous Work Period - At five-minute intervals during the thirty-minute work period, the subject gave his feeling-tone upon the signal "feeling" from the experimenter.

<u>The Rest Period</u> - The importance of absolute relaxation during the rest period was emphasized. Thinking about the task was particularly discouraged. It will be recalled that this rest period was two minutes long for subjects in condition 1, three minutes for those in condition 2, five minutes for those in condition 3, seven minutes for those in condition 4, ten minutes for those in condition 5, and twenty minutes for those in condition 6.

<u>Work after Rest</u> - Before resuming work (for five minutes more) the subject's feeling-tone was checked, the incentive was recalled, and he was reminded to tap the binding post twice upon the "Go" signal.

<u>Work the Following Day</u> - Today, as on the preceding day, feeling-tone was checked, and the incentive was renewed before the "Go" signal was given. Following this, the subject tapped the binding post twice and worked for five minutes.

<u>Raw Performance Scores</u> - Each work sheet was examined for errors by placing over it a correctly punched stencil. The last analogy worked during the thirty-minute work period, the five minutes after rest, and the five minutes the next day had been carefully indicated on the sheets. The chronograph tape was marked off into lengths representing one minute each. The number of problems solved during each minute was found by counting the stylus marks on the tape recorded for each minute. By means of the tape, minute by minute performance could be indicated on each of the analogy sheets. From these sheets were transferred to a separate record card for each subject, the number of problems attempted and number

worked correctly during each minute of work for the thirty-minute work period, for work after rest, and for work the next day. A summary table of the work done during each minute for these three work periods by each member of the group was made for each of the six conditions. See Tables I through VI - Appendix A.

The number of blocks occurring during each minute of work was likewise determined from the chronograph tape. A capital "B" was placed above every response twice as long as an average response. These B's were indicated on the individual record card for the exact minute during which they occurred.

Experimental Procedure with Galvanometric Measurements Included

Introductory Statement - The steps of procedure described in detail in the foregoing were followed with the eight subjects from each of the six conditions for whom skin resistance measurements were made. Necessary additions included: First, attachment of electrodes; second, A fifteen-minute relaxation period before beginning work; third, minute by minute recording of the subject's resistance changes during the thirty minutes of continuous work; fourth, minute by minute recording of the subject's resistance changes during rest period; and fifth, minute by minute recording during the work period after rest.

Acquaintance with Apparatus - Upon entering the experimental room, the subject was shown the apparatus and told that changes in his energy requirements during work and during rest would be measured. It was particularly emphasized that a three-volt dry cell plus the large amount of resistance in the circuit precluded all shock possibility.

Motivation of Subject - See page 45.

Reading Instructions - The instructions for solving analogies were read and preliminary practice given. It was while the subjects were engaged in reading the instructions for checking the feeling-tone scale and selecting their card that the electrodes were attached.

Adjustment of Electrodes - The inactive electrode was adjusted first. The volar part of the arm was vigorously rubbed with electrocardiograph paste. This was used to provide good dermal conductivity. The soaked filter paper followed. Then the zinc plate was strapped down tight enough to insure a constant area contact and pressure, but not tight enough to affect circulation.

The steps in the adjustment of the active electrode to the palm included: First, applying a soaked filter paper; second, applying the rubber sponge which was saturated with kaolin and inserted into the stopper cavity against the zinc plate; and third, strapping down the whole device so as to insure constant pressure and constant area contact.

Preliminary Relaxation Period - This fifteen-minute relaxation period had two purposes. One was to allow opportunity for some measure of recovery from the stimulation effect: First, of activities engaged in before coming to the experimental room; and second, of any apprehension or anxiety occasioned by the rather complicated laboratory set-up. In addition, a curve plotted from changes in resistance and resistance levels during such a period of relative minimum stimulation would provide a very adequate comparative basis for the curve plotted from changes occurring during and as a result of relative maximum stimulation.

Realization of the foregoing two-fold purpose involved two problems, namely, securing complete relaxation of the subject, as well as continuous recording of the changes in galvanometric deflections. The subject was, accordingly, urged to assume at the outset, as comfortable a position as possible and to remain in that position until the end of the rest period. If at any time he experienced discomfort, he was to shift easily with as little effort as possible. He was, furthermore, to keep his eyes closed and to relax as completely mentally as possible, in fact, to fall asleep if he could.

The experimenter in the meantime, after establishing initial resistance, noted the moment by moment delfections in millimeters on the translucent scale. It was a tedious procedure, requiring constant attention to the wanderings of the indicator. Also all of the subject's overt movements which paralleled sudden fluctuations in deflection were recorded.

Continuous Work Period - In addition to the details given on page 46 for this period, it should be emphasized that minute by minute changes in galvanometric deflections were noted by the experimenter. In the same manner also were recorded all of the subject's overt movements and the simultaneously occurring sudden fluctuations in deflection.

Rest Period - The technique for moment by moment notation of changes in galvanometric deflections was the same as in the foregoing. The rest conditions of the preliminary relaxation period were also repeated. For the remaining details of procedure see page 47 .

Work after Rest - The minute by minute recording of galvanometric deflections continued during this period. See page 47 for additional details of procedure of work after rest.

Raw Performance Scores - The individual cards described in the foregoing section of procedure were also prepared for this group.

Record of Resistance Changes - From the galvanometer scale calibrations shown in Table IV on page 157 of Appendix B, the moment by moment resistance changes in ohms during work and during rest were ascertained. The ohmic equivalents per millimeter deflection for distances on the scale ranging from 1 mm. to sixty mm. are given in the table. After converting all millimeter changes into ohmic changes, four curves were plotted for each of the subjects for whom these measures had been secured. On the ordinates of the graphs, changes per 1000 ohms resistance were represented and on the abscissa successive units of time (in minutes). A curve was plotted on such a graph for each subject for the fifteen minutes of preliminary relaxation, for the thirty minutes of continuous work, for the variable rest periods, and for the five minutes after rest. Group curves for the foregoing four periods for each of the conditions were also prepared from summary tables.

Results

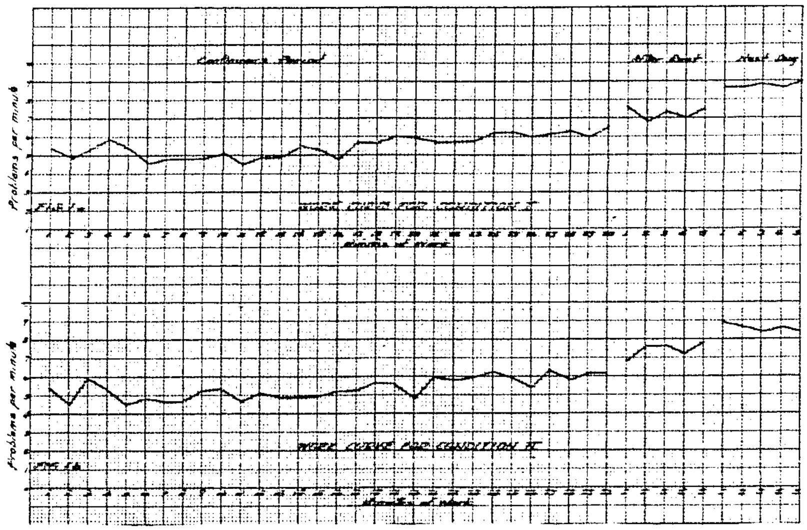
The results of the experimental procedure which did not include measurement of concurrent skin resistance changes will be discussed first as Experiment I. The results of the measurement of skin resistance changes will be identified in later discussion as Experiment II.

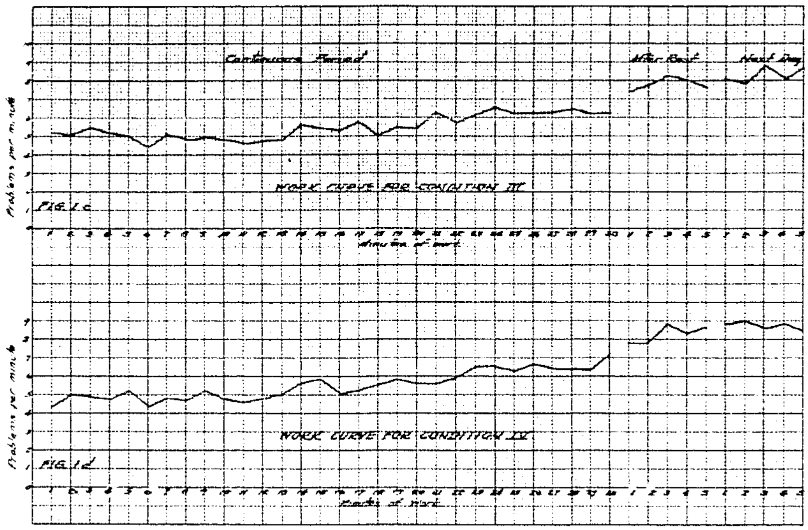
Experiment I

This experiment was concerned with measuring the objective and subjective aspects of recovery. The three objective recovery criteria used were increments in number of problems completed and number worked correctly, and decrease in blocking. A recovery curve was plotted for each of the objective criteria and for subjective feeling-tone changes. The regression line of best fit was obtained for problems completed.

Some significant general observations can be obtained by careful examination of the curves of work for the six conditions. See Figures Ia, Ib, Ic, Id, Ie, and If. For the most part the curves for the thirty minutes of continuous work are characterized by an initial rise during the first three or four minutes, followed by a decrement, and then a gradual rise, beginning between the 14th and 18th minutes. This is according to expectancy for a partially practiced task. The total fatigue effect, or decrement, has apparently been masked by practice effect. In fact, the higher level of performance during the work period after each of the variable rest periods and during work the next day demonstrates that there must have been a concealed fatigue effect at the end of the continuous work period. Also, the fact that the level of performance after each rest period is lower than that of the next day, may be taken as evidence that less recovery from fatigue occurred after each of the six rest periods than after a day's rest.

The changes in performance level shown by the curves are well supported by the data in Table II, which gives the average number of problems worked per minute before rest, after rest, and the next day. In


Continuous Period
After Rest
Next Day
Problems per minute
FIG. 1a
WORK CURVE FOR CONDITION I
Minutes of Work
WORK CURVE FOR CONDITION II
FIG. 1b
Minutes of Work


Continuous Period
After Rest
Next Day
Problems per minute
WORK CURVE FOR CONDITION III
FIG. 1c
Minutes of Work
WORK CURVE FOR CONDITION IV
FIG. 1d
Minutes of Work

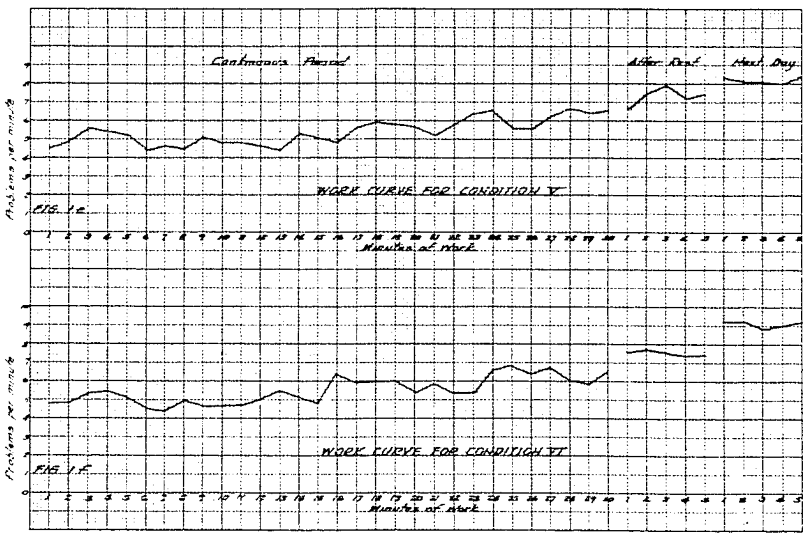

Continuous Period
After Rest
Next Day
Problems per minute
WORK CURVE FOR CONDITION V
FIG. 1e
Minutes of Work
WORK CURVE FOR CONDITION VI
FIG. 1f
Minutes of Work

TABLE II

AVERAGE NUMBER OF PROBLEMS COMPLETED PER MINUTE DURING FOUR FIVE-MINUTE WORK PERIODS

FOR THE SIX EXPERIMENTAL GROUPS

Condition	Continuous Thirty-Minute Period										Five Minutes of Work after Rest					Five Minutes of Work next Day				
	First 5 Min.					Last 5 Min.														
I	5.2	4.9	5.4	5.9	5.4	6.0	6.1	6.3	6.0	6.5	7.6	6.8	7.3	7.0	7.5	8.7	8.7	8.8	8.7	9.0
II	5.4	4.5	5.8	5.3	4.5	5.4	6.3	5.8	6.1	6.1	6.8	7.6	7.6	7.2	7.8	8.9	8.6	8.4	8.6	8.4
III	5.2	5.1	5.5	5.2	5.0	6.2	6.2	6.4	6.2	6.3	7.4	7.7	8.2	8.0	7.6	8.0	7.9	8.8	8.0	8.6
IV	4.3	5.0	4.9	4.8	5.2	6.6	6.4	6.4	6.3	7.1	7.9	7.8	8.8	8.3	8.6	8.8	8.9	8.6	8.8	8.2
V	4.5	4.8	5.6	5.4	5.2	5.6	6.2	6.6	6.4	6.5	6.6	7.4	7.8	7.2	7.4	8.3	8.1	8.1	8.0	8.3
VI	4.9	4.9	5.3	5.4	5.1	6.4	6.7	6.0	5.9	6.5	7.6	7.7	7.5	7.4	7.4	9.2	9.2	8.8	9.0	9.2

general, the last five minutes of continuous work shows improvement over the first five minutes. This would seem to indicate, on the surface, a practice effect rather than a fatigue effect. But the increase in performance level immediately after rest over that immediately before rest, suggests a gain of lost efficiency. This lost efficiency must have been masked by the practice effect at the end of the continuous work period.

Computation of recovery percentages or ratios was based on the comparison of the performance scores made during three five-minute work periods, that is, the periods immediately preceding rest, immediately following rest, and the next day. The criteria of the efficiency of performance used have already been pointed out. In Table III the marked changes in average performance from one to the other of these five-minute periods are clearly brought out. The data in the table demonstrate unequivocally objective recovery for each of the six conditions. The reliability of the differences in the performance levels of the three five-minute work periods is shown by the critical ratios in Table IV for problems completed, and in Table VII of Appendix A for problems worked correctly. From the magnitude of these ratios, we may conclude that the differences are statistically significant.

Results up to this point hage simply demonstrated absolute amounts of recovery after each of the six rest periods. There remain for consideration, therefore: First, the percentage of total recovery occurring after each of the six rest periods, for each of the three objective criteria; second, the graphical representation of the relationship between these ratios and their respective minutes of rest; third,

TABLE III

COMPARISON OF THE THREE FIVE-MINUTE WORK PERIODS UNDER THE SIX CONDITIONS FOR THE THREE CRITERIA OF OBJECTIVE RECOVERY

Condition	Av. No. of Problems Completed			Av. No. of Problems Worked Correctly			Total Number of Blocks		
	M_1	M_2	M_3	M_1	M_2	M_3	T_1	T_2	T_3
I	31.0	36.3	43.9	29.0	34.3	41.7	49	47	37
II	29.6	37.0	42.9	27.6	35.2	40.8	46	43	38
III	31.3	38.9	41.5	29.4	36.8	39.0	49	42	38
IV	32.7	41.3	43.2	30.8	39.6	40.9	47	43	41
V	31.3	36.5	40.9	29.7	34.4	38.3	48	47	44
VI	31.4	37.5	45.4	29.4	34.9	42.3	48	47	40

M_1 = Av. No. of Problems Worked during the last 5 min. of the Continuous Work Period
M_2 = Av. No. of Problems Worked during five minutes Immediately after Rest
M_3 = Av. No. of Problems Worked during five minutes the Following Day

TABLE IV

COMPARISON OF AVERAGES, STANDARD DEVIATIONS, STANDARD ERRORS, AND CRITICAL RATIOS

FOR TOTAL NUMBER OF PROBLEMS COMPLETED FOR THE SIX DIFFERENT GROUPS

Conditions	Averages			Standard Deviation			Standard Errors			σ/D & C R's		σ/D & C R's	
	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_2-M_1	M_2 M_1	M_3-M_1	M_3 M_1
I	31.0	36.3	43.9	8.56	9.99	9.82	1.71	1.99	1.96	1.04	5.1	.93	13.8
II	29.6	37.0	42.9	9.68	11.52	13.30	1.93	2.30	2.66	.96	7.14	1.36	9.7
III	31.3	38.9	41.5	11.27	12.64	11.94	2.25	2.52	2.38	1.14	6.67	.94	10.9
IV	32.7	41.3	43.2	10.60	11.61	11.98	2.12	2.32	2.39	.79	10.92	1.24	8.5
V	31.3	36.5	40.9	8.89	10.19	11.45	1.79	2.04	2.29	.81	6.56	1.14	8.2
VI	31.4	37.5	45.4	9.93	11.17	11.22	1.99	2.23	2.24	1.22	5.02	1.32	10.6

the regression line of best fit for problems completed; and fourth, the curve of recovery for subjective feeling-tone. The regression line of best fit was limited to problems completed because the empirical curves for problems worked correctly and for blocking are similar to that for problems completed.

In Tables VI, VII, VIII, IX, X, and XI are found the recovery ratios for each subject for each of the six conditions. These ratios are based on problems completed. They were computed by substituting, in the formula $\frac{S_2 - S_1}{S_3 - S_1}$, values obtained from the actual observations. Details for the derivation of the formula were given under the caption "Preliminary procedure".

Tables VIII, IX, X, XI, XII, and XIII found in Appendix A present similar data for problems worked correctly. The facts for blocking are presented in Table V.

The mean of the individual recovery ratios for problems completed and problems worked correctly yielded group ratios for each of the six conditions.

The recovery ratios for the three output criteria are summarized in Table XII, page . The graphical representation of the relationship between these ratios and minutes of rest is found in the curves of Figures 2a, 2b, and 2c. It will be seen that the general form of the three curves is quite similar. There is a tendency toward negative acceleration up to the seven-minute rest period, followed by a decided drop for the ten-minute period and another much less marked drop for the twenty-minute period. The facts demonstrate, further, that there is an optimum rest period of seven minutes and that the gain in efficiency was much greater for two and

TABLE V

COMPARISON OF CONDITIONS I THRU VI AS TO CHANGES IN PERFORMANCE FROM ONE TO THE OTHER OF THE THREE WORK PERIODS IN TERMS OF BLOCKING

Condition	Last 5 Min.	After Rest	Next Day	Change Bet. I & II	Change Bet. I & III	Ratio Bet. IV & V
I	49	47	37	2	12	16.6%
II	46	43	38	3	8	37.5%
III	49	42	38	7	11	63.6%
IV	47	43	41	4	6	66.6%
V	48	47	44	1	4	25.0%
VI	48	47	40	1	8	12.5%

TABLE VI

RECOVERY RATIOS IN TERMS OF PROBLEMS ATTEMPTED FOR EACH SUBJECT FOR CONDITION I

	I	II	III	IV	V	VI	VII
Subject	Continuous Work Period		Test Immediately after Rest	Test Next Day	Change Bet. II & III	Change Bet. II & IV	Ratio Bet. V & VI
	1st 5 Min.	Last 5 Min.					
I A	19	28	35	41	7	13	53.8
I B	36	39	46	54	7	15	46.7
I C	29	46	55	61	9	15	60.0
I D	15	12	25	34	13	22	59.1
I E	29	39	38	50	- 1	11	- 9.1
I F	18	27	36	47	9	20	45.0
I G	41	41	59	62	18	21	85.7
I H	43	48	46	58	- 2	10	-20.0
I I	26	37	40	50	3	13	23.1
I J	35	25	30	40	5	15	33.3
I K	31	37	48	57	11	20	55.0
I L	24	19	20	25	1	6	16.7
I M	28	35	39	41	4	6	66.7
I N	24	30	33	49	3	19	15.8
I O	20	22	29	31	7	9	77.8
I P	21	22	28	32	6	10	60.0
I Q	19	24	24	31	0	7	0
I R	22	22	21	30	- 1	8	-12.5
I S	26	25	29	40	4	15	26.7
I T	21	28	38	43	10	15	66.7
I U	35	28	35	40	7	12	58.3
I V	25	36	40	47	4	11	36.4
I W	33	37	41	47	4	10	40.0
I X	28	36	35	45	- 1	9	-11.1
I Y	26	33	38	44	5	11	45.5
Total	674	776	908	1099	132	323	919.6
Average	26.9	31.0	36.3	43.9	5.3	12.9	36.8

TABLE VII

RECOVERY RATIOS IN TERMS OF PROBLEMS ATTEMPTED FOR EACH SUBJECT FOR CONDITION II

	I	II	III	IV	V	VI	VII
Subject	Continuous Work Period		Test Immediately after Rest	Test Next Day	Change Bet. II & III	Change Bet. II & IV	Ratio Bet. V & VI
	1st 5 Min.	Last 5 Min.					
II A	25	26	38	52	12	26	46.2
II B	21	24	33	47	9	23	39.1
II C	19	22	24	28	2	6	33.3
II D	27	38	42	54	4	16	25.0
II E	27	53	60	62	7	9	77.8
II F	34	35	36	47	1	12	8.3
II G	13	16	24	24	8	8	100.0
II H	15	14	21	23	7	9	77.8
II I	20	26	30	38	4	12	33.3
II J	25	27	29	34	2	7	28.6
II K	19	30	31	41	1	11	9.1
II L	33	45	57	56	12	11	109.0
II M	37	48	57	65	9	17	53.0
II N	38	43	61	70	18	27	70.4
II O	23	25	35	30	10	5	200.0
II P	36	32	45	54	13	22	59.1
II Q	16	15	22	20	7	5	140.0
II R	28	30	38	50	8	20	40.0
II S	20	34	43	49	9	15	60.0
II T	28	32	38	45	6	13	46.2
II U	13	24	37	37	13	13	100.0
II V	22	23	23	31	0	8	00.0
II W	21	25	37	36	12	11	109.0
II X	30	29	33	38	4	9	44.4
II Y	40	25	32	42	7	17	41.2
Total	630	741	926	1073	185	332	1550.8
Average	25.2	29.6	37.0	42.9	7.4	13.3	62.0

TABLE VIII

RECOVERY RATIOS OF PROBLEMS ATTEMPTED FOR EACH SUBJECT FOR CONDITION III

	I	II	III	IV	V	VI	VII
Subject	Continuous Work Period		Test Immediately after Rest	Test Next Day	Change Bet. II & III	Change Bet. II & IV	Ratio Bet. V & VI
	1st 5 Min.	Last 5 Min.					
III A	22	28	30	38	2	10	20.0
III B	19	21	30	31	9	10	90.0
III C	28	29	39	37	10	8	125.0
III D	27	36	38	42	2	6	33.3
III E	41	56	59	60	3	4	75.0
III F	18	27	35	35	8	8	100.0
III G	29	40	49	49	9	9	100.0
III H	18	24	34	35	10	11	91.0
III I	23	18	26	32	8	14	57.1
III J	25	26	27	28	1	2	50.0
III K	22	21	31	31	10	10	100.0
III L	47	59	72	73	13	14	92.8
III M	27	37	40	43	3	6	50.0
III N	21	19	22	24	3	5	60.0
III O	24	25	28	34	3	9	33.3
III P	21	26	40	48	14	22	63.6
III Q	25	23	23	27	0	4	00.0
III R	22	26	34	36	8	10	80.0
III S	32	43	51	56	8	13	61.5
III T	17	25	37	45	12	20	60.0
III U	19	29	36	35	7	6	116.8
III V	40	36	40	46	4	10	40.0
III W	34	42	55	57	13	15	86.6
III X	15	21	39	35	18	14	128.00
III Y	35	45	59	58	14	13	107.70
Total	651	782	974	1035	192	253	1821.7
Average	26.0	21.3	38.9	41.5	7.7	10.2	72.8

TABLE IX

RECOVERY RATIOS IN TERMS OF PROBLEMS ATTEMPTED FOR EACH SUBJECT FOR CONDITION IV

	I	II	III	IV	V	VI	VII
Subject	Continuous Work Period		Test Immediately after Rest	Test Next Day	Change Bet. II & III	Change Bet. II & IV	Ratio Bet. V & VI
	1st 5 Min.	Last 5 Min.					
IV A	19	24	26	27	2	3	66.7
IV B	17	28	32	36	4	8	50.0
IV C	32	43	48	47	5	4	125.0
IV D	38	40	52	61	12	21	57.1
IV E	24	24	31	31	7	7	100.0
IV F	22	31	42	40	11	9	122.2
IV G	18	26	41	39	15	11	136.3
IV H	19	27	37	41	10	14	71.4
IV I	29	47	49	49	2	2	100.0
IV J	19	28	32	35	4	7	57.1
IV K	42	52	58	62	6	10	60.0
IV L	33	46	57	57	11	11	100.0
IV M	33	42	55	58	13	16	81.3
IV N	22	29	42	50	13	21	61.9
IV O	27	31	42	41	11	10	110.0
IV P	14	17	31	30	14	13	107.8
IV Q	16	15	25	27	10	12	83.4
IV R	10	22	25	26	3	4	75.0
IV S	25	33	43	49	10	16	62.5
IV T	19	27	33	37	6	10	60.0
IV U	23	54	58	60	4	6	66.7
IV V	34	43	62	68	19	25	76.0
IV W	30	39	47	48	8	9	88.9
IV X	18	28	33	33	5	5	100.0
IV Y	22	22	32	32	10	10	100.0
Total	605	818	1033	1082	215	264	2119.3
Average	24.2	32.7	41.3	43.2	8.6	10.5	84.77

TABLE X

RECOVERY RATIOS IN TERMS OF PROBLEMS ATTEMPTED FOR EACH SUBJECT FOR CONDITION V

	I	II	III	IV	V	VI	VII
Subject	Continuous Work Period		Test Immediately after Rest	Test Next Day	Change Bet. II & III	Change Bet. II & IV	Ratio Bet. V & VI
	1st 5 Min.	Last 5 Min.					
V A	16	15	20	22	5	7	71.4
V B	27	32	37	48	5	16	31.3
V C	29	29	33	40	4	11	36.4
V D	38	43	57	62	14	19	73.7
V E	21	27	30	35	3	8	37.5
V F	19	25	29	35	4	10	40.0
V G	21	35	37	44	2	9	22.2
V H	19	18	18	21	0	3	00.0
V I	33	31	38	42	7	11	63.6
V J	38	57	57	61	0	4	00.0
V K	35	38	48	54	10	16	62.5
V L	31	36	42	43	6	7	85.7
V M	21	28	36	37	8	9	88.9
V N	32	35	49	60	14	25	56.0
V O	19	21	23	31	2	10	20.0
V P	19	23	23	23	0	0	00.0
V Q	24	26	30	31	4	5	80.0
V R	28	39	41	50	2	11	18.2
V S	19	34	37	51	3	17	17.6
V T	28	22	32	31	10	9	111.1
V U	23	39	48	47	9	8	112.5
V V	26	32	35	34	3	2	133.3
V W	23	29	34	39	5	10	50.0
V X	30	42	44	46	2	4	50.0
V Y	19	27	34	37	7	10	70.0
Total	638	783	912	1024	129	241	1331.9
Average	25.5	31.3	36.5	40.9	5.2	9.6	53.3

TABLE XI

RECOVERY RATIOS IN TERMS OF PROBLEMS ATTEMPTED FOR EACH SUBJECT FOR CONDITION VI

	I	II	III	IV	V	VI	VII
Subject	Continuous Work Period		Test Immediately after Rest	Test Next Day	Change Bet. II & III	Change Bet. II & IV	Ratio Bet. V & VI
	1st 5 Min.	Last 5 Min.					
VI A	29	33	36	43	3	10	30.0
VI B	18	21	22	27	1	6	16.7
VI C	34	33	41	47	8	14	57.1
VI D	21	28	34	42	6	14	42.9
VI E	26	25	32	33	7	8	87.5
VI F	14	24	25	50	1	26	3.8
VI G	22	30	33	40	3	10	30.0
VI H	13	35	45	55	10	20	50.0
VI I	28	30	32	54	2	24	8.3
VI J	23	30	36	43	6	13	46.2
VI K	26	39	39	41	0	2	00.0
VI L	23	24	42	41	18	17	104.9
VI M	30	39	40	58	1	19	5.3
VI N	26	31	34	39	3	8	37.5
VI O	13	24	46	53	22	29	75.9
VI P	19	21	21	28	0	7	00.0
VI Q	19	21	30	33	9	12	75.0
VI R	30	33	42	46	9	13	69.2
VI S	28	31	34	37	3	6	50.0
VI T	64	68	72	80	4	12	33.3
VI U	19	20	26	34	6	14	42.9
VI V	19	26	37	48	11	22	50.0
VI W	27	35	36	43	1	8	12.5
VI X	30	36	41	58	5	22	22.7
VI Y	40	48	62	62	14	14	100.0
Total	641	785	938	1135	153	350	1051.7
Average	25.6	31.4	37.5	45.4	6.1	14.0	42.1

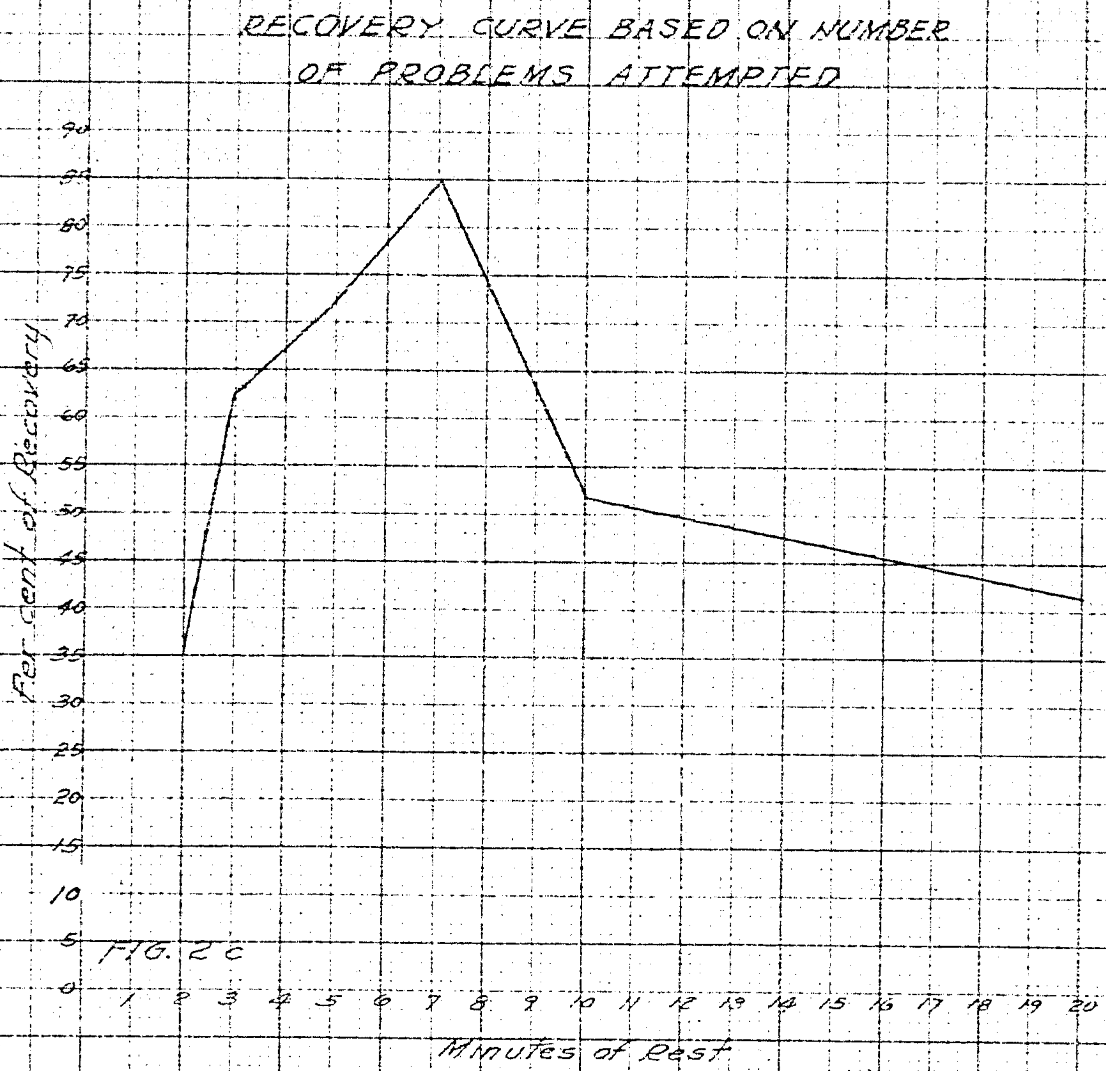

RECOVERY CURVE BASED ON NUMBER OF PROBLEMS ATTEMPTED
Per cent of Recovery
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Minutes of Rest

FIG. 2 c

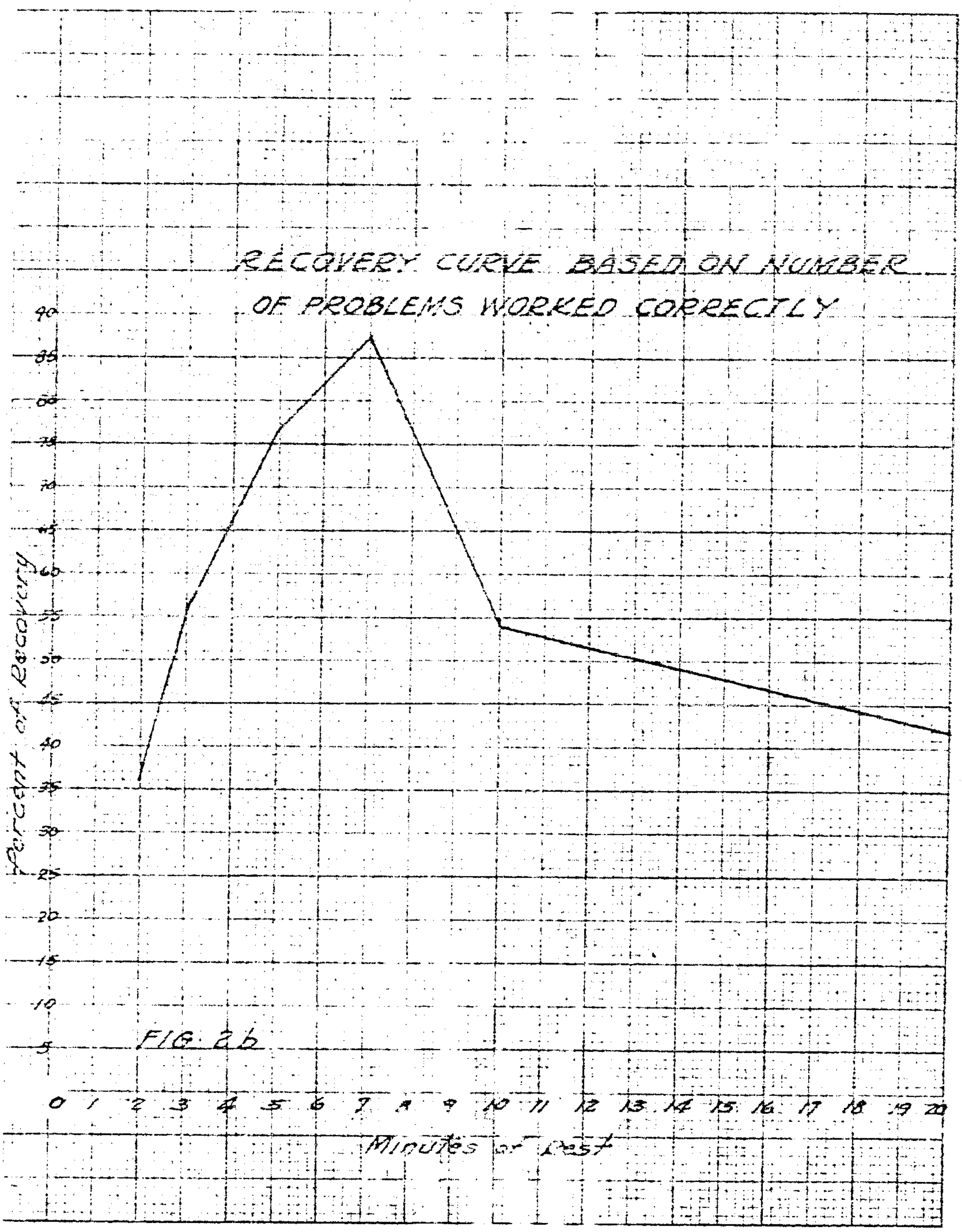
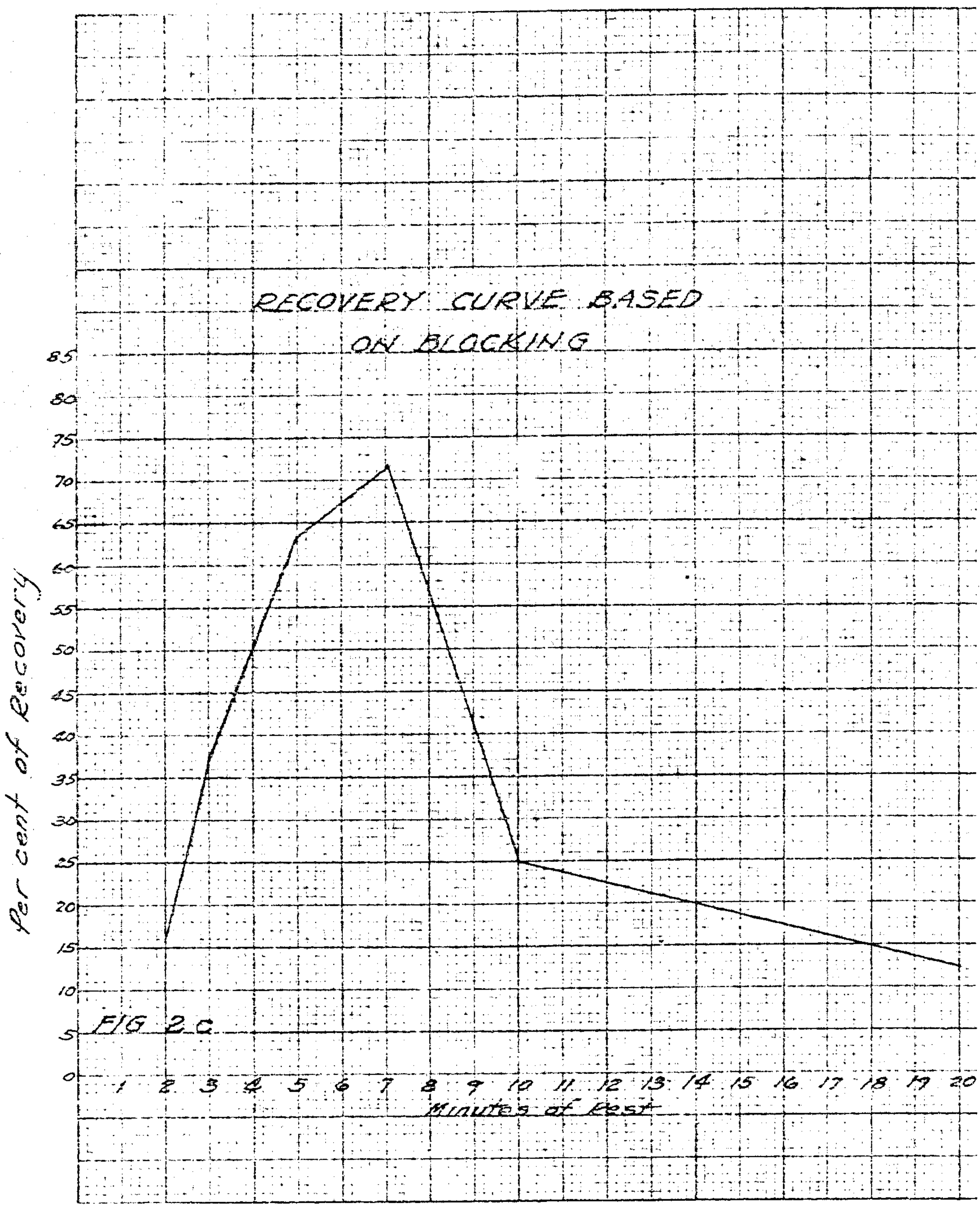

RECOVERY CURVE BASED ON NUMBER
OF PROBLEMS WORKED CORRECTLY
Percent of Recovery
Minutes of Rest
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIG. 2b


RECOVERY CURVE BASED
ON BLOCKING
Per cent of Recovery
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Minutes of Rest
FIG 2 c

three-minute rest periods than for the ten and twenty-minute periods. The gains in efficiency shown in Table XII for problems completed and problems worked correctly were of a higher order than those in terms of blocking. Let it be emphasized that "rest period" in this investigation must be identified with a relative minimum reactivity level as judged and assumed by each subject. In other words,the subject was instructed to relax completely.

To make sure that the empirically derived changes in recovery ratios were in the main a function of changes in minutes of rest rather than a function of extraneous factors, Fisher's test of the existence of correlation was applied. The method consists essentially in comparing the sum of the squares of the deviations of the individual observations from the means of their arrays and that of the means of the arrays from the general mean. In brief, it consists of the comparison of the mean variance within arrays and that between arrays. If these variances are equal, the correlation between the variates in question is zero. On the other hand, the significance of any discovered difference between the variances is dependent upon its "z" value.

The reader is referred to Appendix C for the computations relative to the "Test of Existence of Correlation" and the determination of the "regression lines of best fit". On page 161 the value of "z" will be found to be 0.99468 which according to Fischer's "z" table permitted us to conclude that the hypothesis of correlation between recovery ratios and minutes of rest is tenable.

Since the relationship between the recovery ratios and minutes of rest was found to be statistically significant, the regression line

TABLE XII

RECOVERY RATIOS FOR THE THREE OUTPUT CRITERIA FOR THE SIX EXPERIMENTAL GROUPS

Condition	Percentage of Problems Completed	Percentage of Problems Worked Correctly	Percentage of Blocking
I - 2 Minutes Rest	36.78	37.70	16.6
II - 3 Minutes Rest	62.032	65.25	37.5
III - 5 Minutes Rest	72.86	79.26	63.6
IV - 7 Minutes Rest	84.77	86.30	66.6
V - 10 Minutes Rest	53.27	54.90	25.0
VI - 20 Minutes Rest	42.06	44.47	12.5

of best fit was sought. That is to say, the curve ordinates to be represented on the graph used for plotting the theoretical curve of best fit had to be calculated. As seen from Appendix C, this was a more or less trial and error process. Neither the first degree equation nor the second degree equation seemed adequate for the expression of the law of relationship between ratio of recovery and minutes of rest. However, the third degree equation, expressed below, seemed to suffice for the statement of the law of this relationship.

$$Y_c = 54.7265584 - 10.943417X - 0.4769747X^2 + 0.1444317X^3$$

In Table XIII, the values of the curve ordinates derived from each of these equations are presented. The correspondence between the empirical values and the third degree equation values is quite marked. In Figure 3, the three regression lines are plotted. Here the close fit of the third degree curve to the empirical data is emphasized. This is true up to ten minutes of rest, at least. It is unfortunate that no observations were made for rest periods between ten minutes and twenty. But breaking up this interval at the outset of experimentation seemed unessential in view of this investigator's expectation of a simple negatively accelerated curve of recovery, with the curve after the twenty-minute point tending to become asymtotic to the initial unfatigued level. Without observations for rest periods between ten minutes and twenty minutes, the direction of the curve between these two intervals cannot be determined. That is to say, the form of the curve depends upon the distribution of the observations for rest periods spaced at varying intervals between these points.

As has been pointed out, the optimal empirically determined rest

TABLE XIII

EMPIRICALLY DERIVED AND THEORETICALLY DERIVED RECOVERY RATIOS

Condition	Empirical Ratios	Degree of Equation		
		First	Second	Third
I - 2 Minutes of Rest	36.784	63.011	50.834	37.798
II - 3 Minutes of Rest	62.032	62.261	55.828	58.419
III - 5 Minutes of Rest	72.868	60.760	63.837	79.465
IV - 7 Minutes of Rest	84.772	59.259	69.207	79.364
V - 10 Minutes of Rest	53.276	57.007	72.313	54.727
VI - 20 Minutes of Rest	42.068	49.502	39.780	42.027

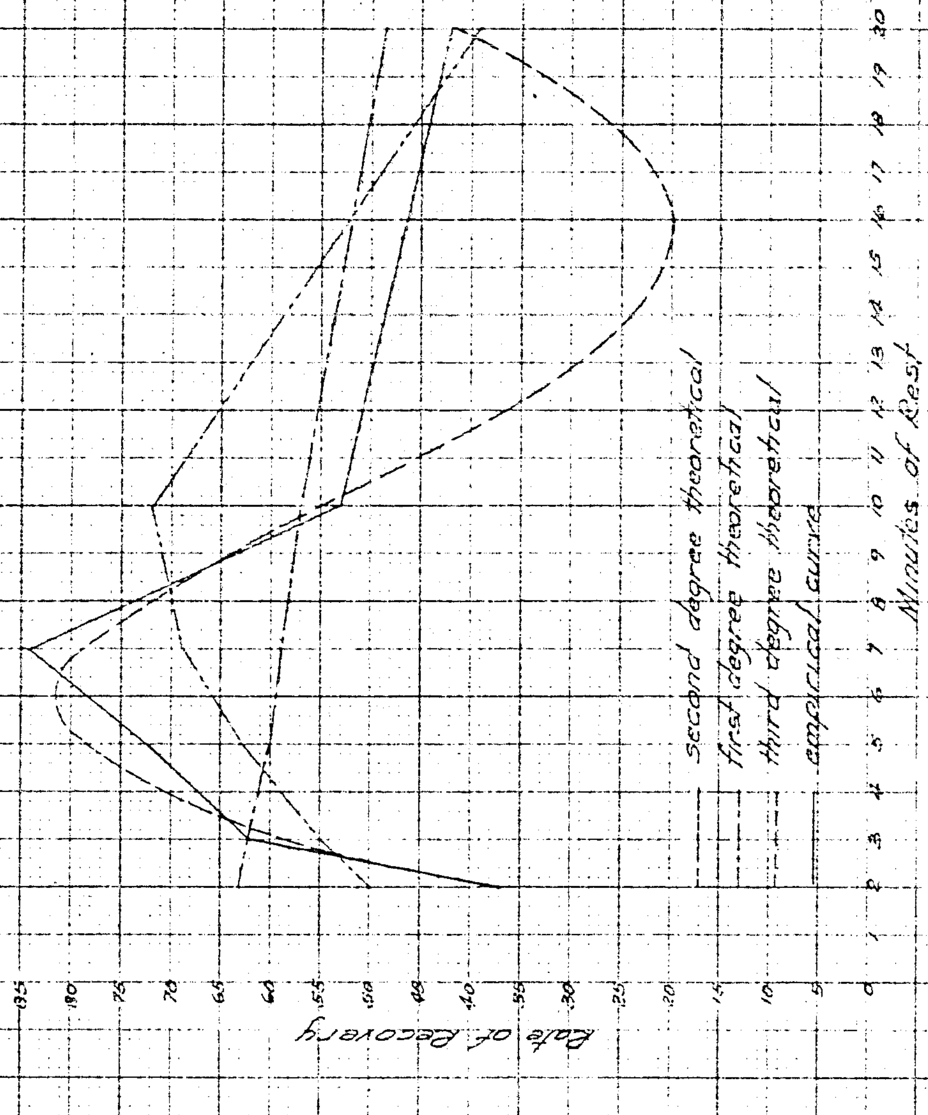


Fig. 3 The empirical curve and three theoretical curves

period was found to be seven minutes. Reference to Figure 3 and tp page 170 of Appendix C shows the mathematically determined maximum point of the third degree equation to be six minutes. The minimum point indicated at 16.25 minutes is purely theoretical. Its location is not supported by experimental data. Such data may change its position radically. For example, it is possible that the minimum would be found to lie at twenty-five minutes. In general, then, the only tenable conclusion from the results obtained in these investigations is that the minimum is located somewhere after ten minutes and before twenty-four hours.

The recovery facts for subjective feeling-tone are presented in Table XIV. For making convenient comparison with output ratios, recovery percentages for problems completed are included in the table. The graphical representation of the relationship between the feeling-tone ratios and minutes of rest is shown in Figure 4.

Both the data of Table XIV and the curve, Figure 4, indicate progressive improvement in feeling-tone with increase in rest up to seven minutes. Seven minutes is shown as the optimum rest period. The minimum increment occurred after a ten-minute rest. An actual decrement of thirty per cent in desire to resume work was observed after twenty minutes of rest. A resemblance in general form through ten minutes of rest (see Figures 2 and 4) will be recognized between the objective and subjective recovery curves. After twenty minutes of rest, on the other hand, an increment of 42 per cent in output is contrasted with a decrement of 30 per cent in feeling-tone. Seven minutes of rest was shown by both curves as the optimum rest period.

<u>Summary Statement</u> - In general, the evidence reviewed thus far

TABLE XIV

RECOVERY RATIOS FOR SUBJECTIVE FEELING TONE VALUES FOR THE SIX EXPERIMENTAL CONDITIONS

	I	II	III	IV	V	VI	VII	VIII
Condition	Initial Work Period		Check Immediately after Rest	Check the Next Day	Change Bet. II & III	Change Bet. II & IV	Ratio Bet. V & VI	Ratio for Problems Completed
	1st 5 Min.	Last 5 Min.						
I - 2 Min.	230	198	202	219	4	21	19%	36.7
II - 3 Min.	215	191	204	217	13	26	50%	62.0
III - 5 Min.	207	191	203	213	12	22	55%	72.8
IV - 7 Min.	218	184	213	220	27	36	80%	84.7
V - 10 Min.	209	190	192	214	2	24	8%	53.2
VI - 20 Min.	214	197	191	217	- 6	20	-30%	42.0

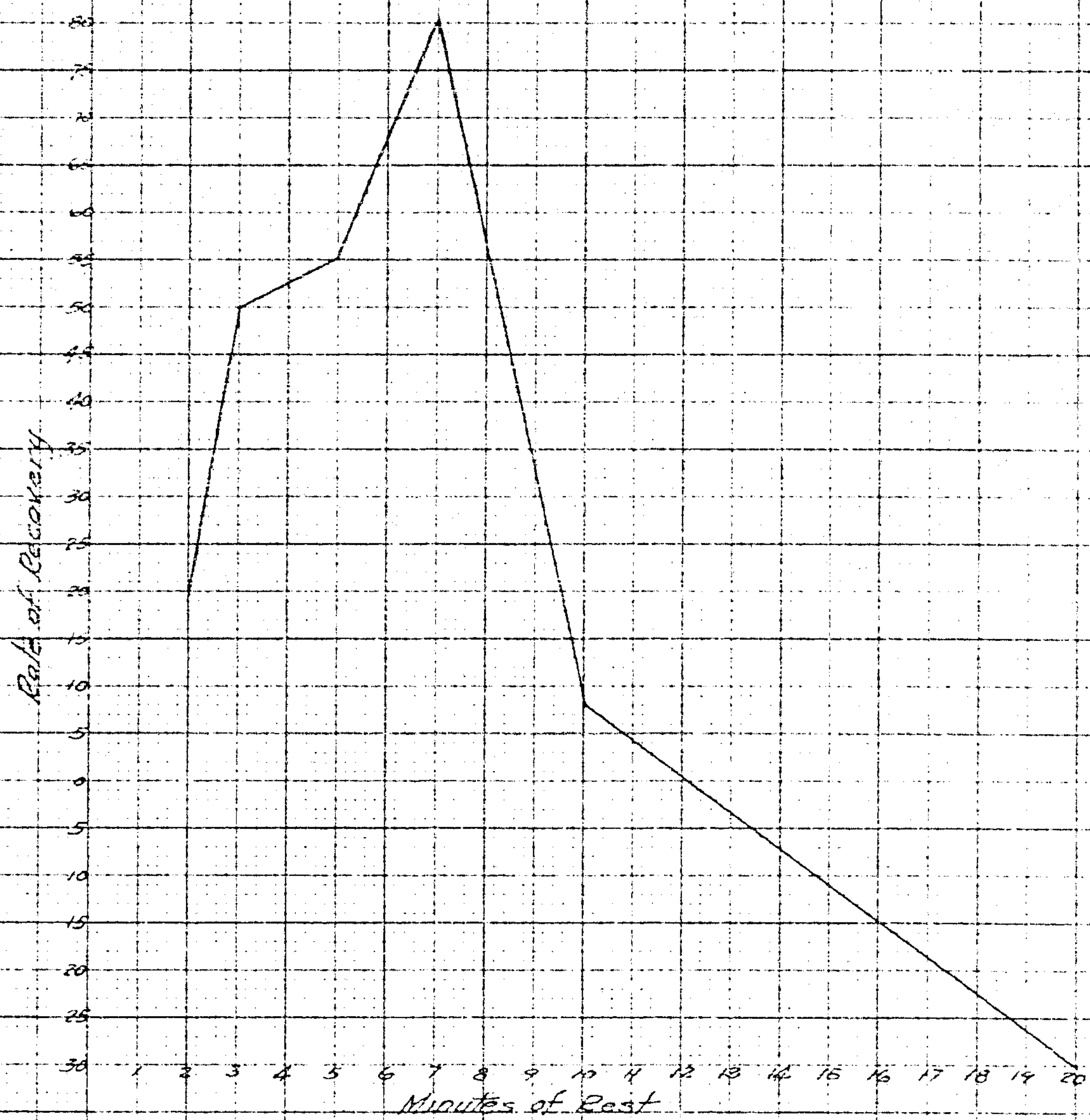


Fig. 4 Recovery curves for subjective feeling tone

demonstrated an optimal rest period of seven minutes, with a greater gain in efficiency after three and five minutes of rest than after ten and twenty minutes. This is true for both the objective and subjective aspects of recovery. Furthermore, the third degree regression equation was found to suffice as a mathematical statement of the relationship between recovery ratios and minutes of rest. The maximal point of the equation and consequently of the sinusoidal curve was determined as six minutes, and the minimal point as 16.25 minutes.

Experiment II

This experiment is concerned with the study of the skin resistance changes that operated concomitantly with changes in mental function. It will be recalled that skin resistance changes were intended to reflect changes in organic state, the third aspect of the study of recovery from mental fatigue. The chief points for consideration included: First, the manner in which changes in mental function were reflected by the skin resistance changes; and second, the relationship, if any, which exists between skin resistance changes during post-work rest periods and increment in output and subjective feeling-tone after rest.

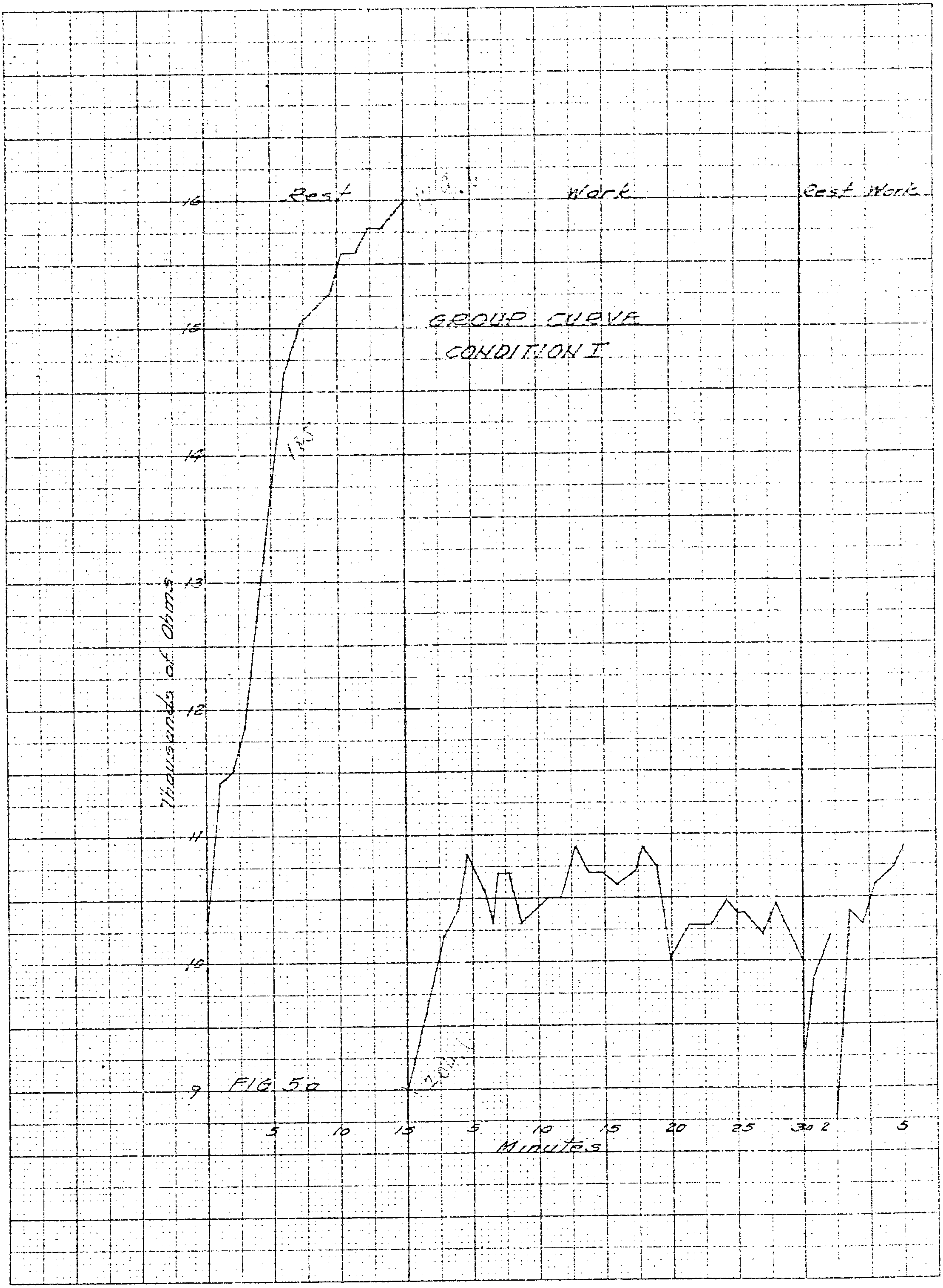
As was pointed out in the foregoing section, a moment by moment record of skin resistance changes was kept for eight subjects in each condition during fifteen minutes of preliminary rest, during thirty minutes of continuous work, during rest immediately after this work and during the five minutes of work the next day. Both individual and group curves were plotted from these continuous records, in an attempt to show the relationship which exists between progressive changes in skin resistance and successive units of time. The curves for two subjects of each condition are reproduced in Figures 5b through 10c. See Appendix A. Group curves for each condition were based on averages of the eight individual scores. See Figures 5a through 10a for the six group cruves.

Skin Resistance Changes and Changes in Mental Function

Characteristics of the Curves of Rest - Examination of all the skin resistance curves shown in Figures 5a through 10a reveals a striking contrast between the curves of relaxation and the curves for work. This is equally true for the curves of the individual subjects and for the group curves. It is also just as true for the post-work curves of rest as for the pre-work curves.

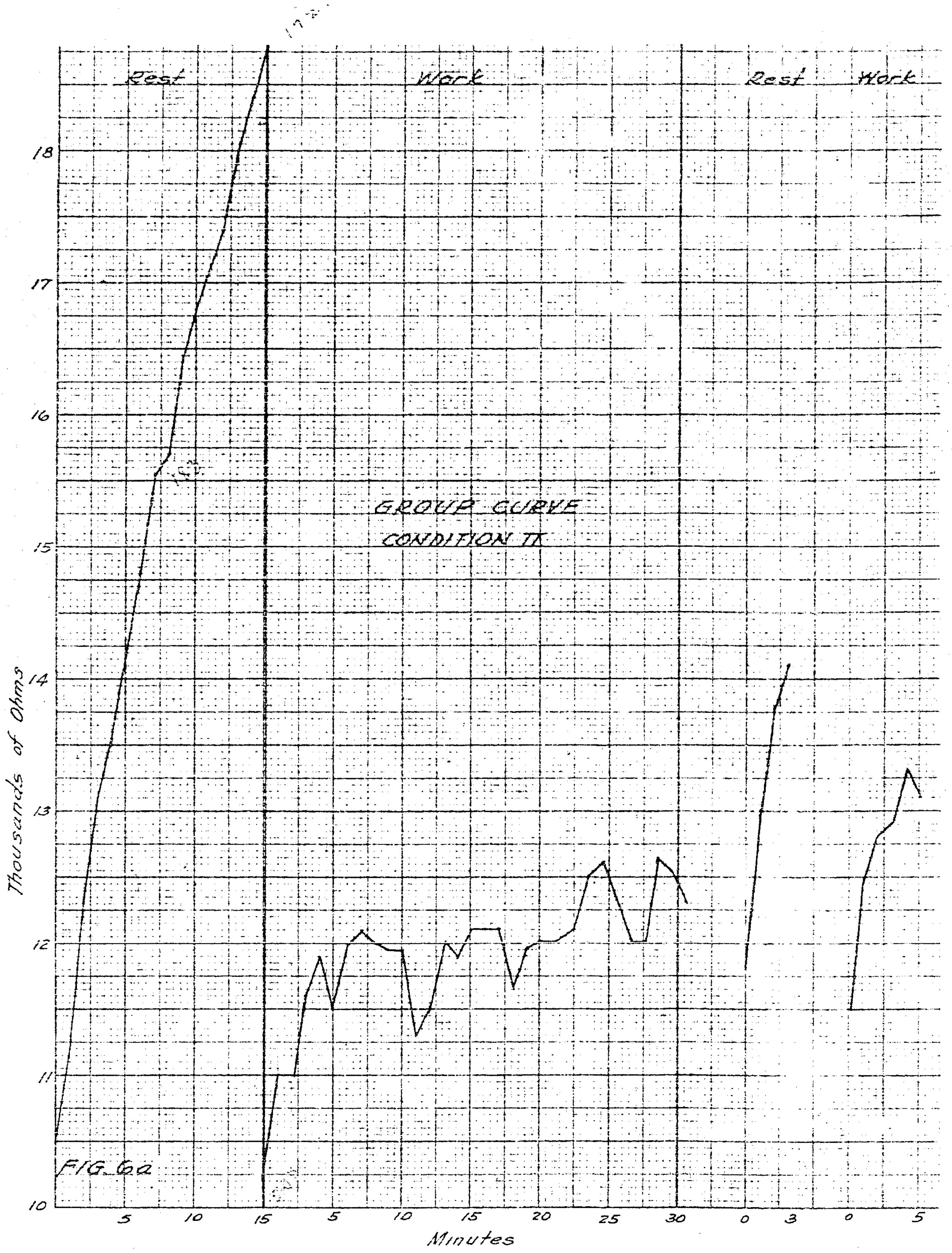
Certain of the more general characteristics of all of these curves of rest include: First, a progressive increase in resistance with the passage of time; second, a tendency toward negative accelertion; and third, a smoothness and regularity, which is interrupted by sudden fluctuations only in a few exceptional cases. In Richter's terms, the curves may be said to represent prolonged variations in resistance interrupted in relatively few cases by sudden transitory changes. According to him, as well as to some other investigators, among the correlates of the sudden, transitory changes are, voluntary movement of the skeletal musculature, clearing the throat, deep breathing, sighing, coughing, emotional stimuli, and blocking in comprehension.

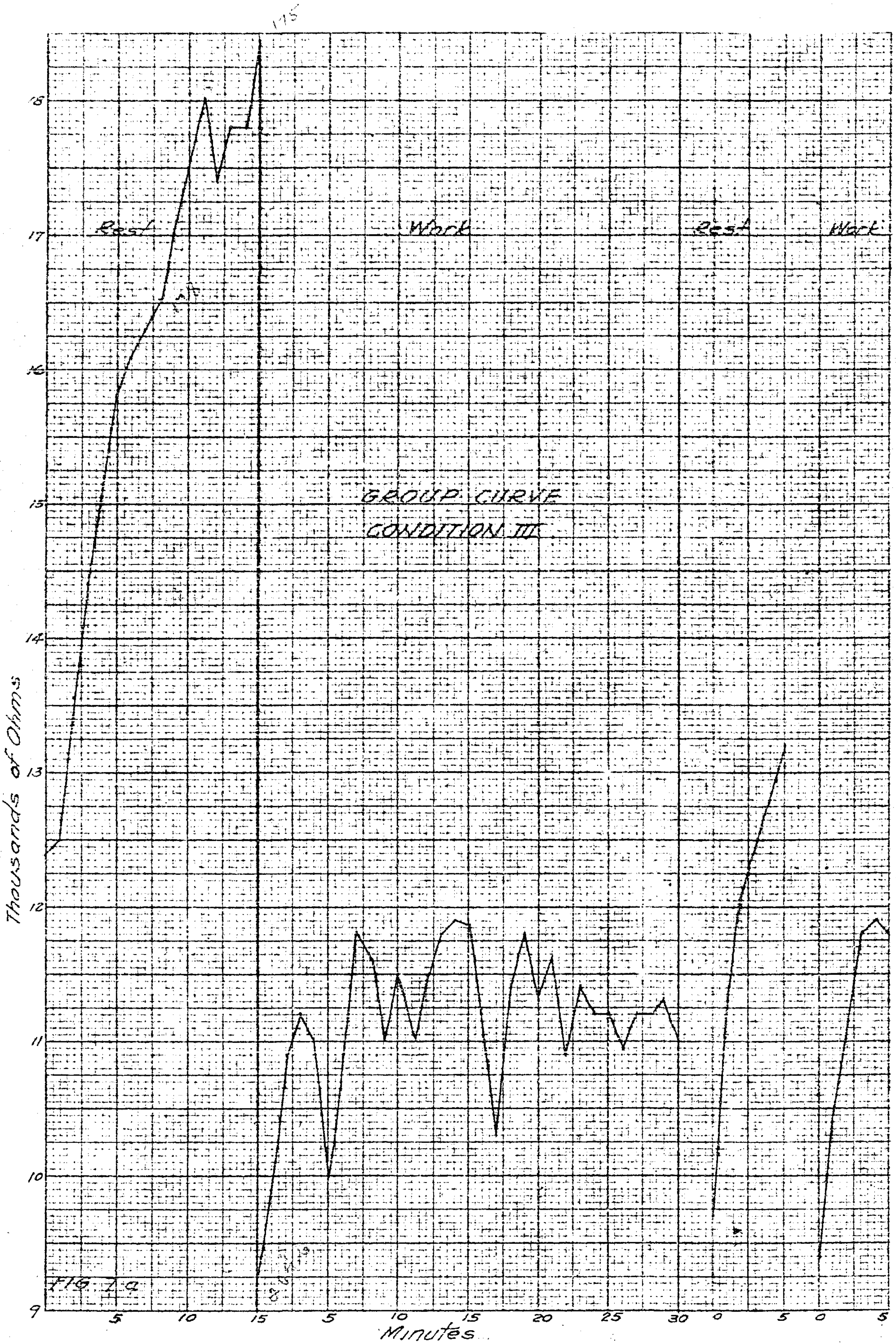
Because of the nature of the relaxation period during the present investigation, the foregoing patterns of behavior were infrequent.



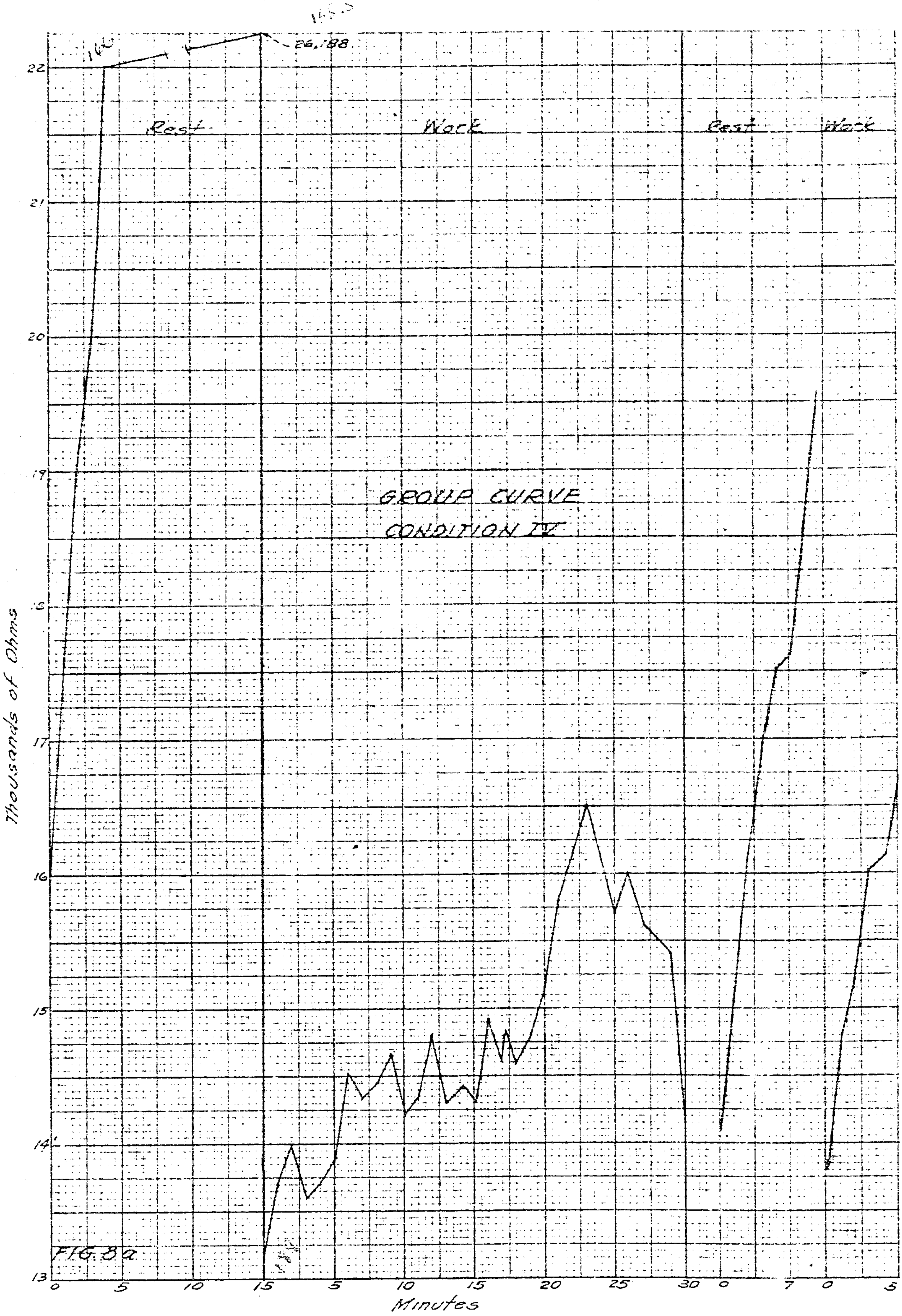
Rest
Work
Rest
Work
GROUP CURVE
CONDITION I
Thousands of Ohms
16
15
14
13
12
11
10
9
5
10
15
5
10
15
20
25
30
2
5
Minutes

FIG. 5a


Rest
Work
Rest
Work
GROUP CURVE
CONDITION II
Thousands of Ohms
18
17
16
15
14
13
12
11
10
FIG. 6a
5
10
15
5
10
15
20
25
30
0
3
0
5
Minutes

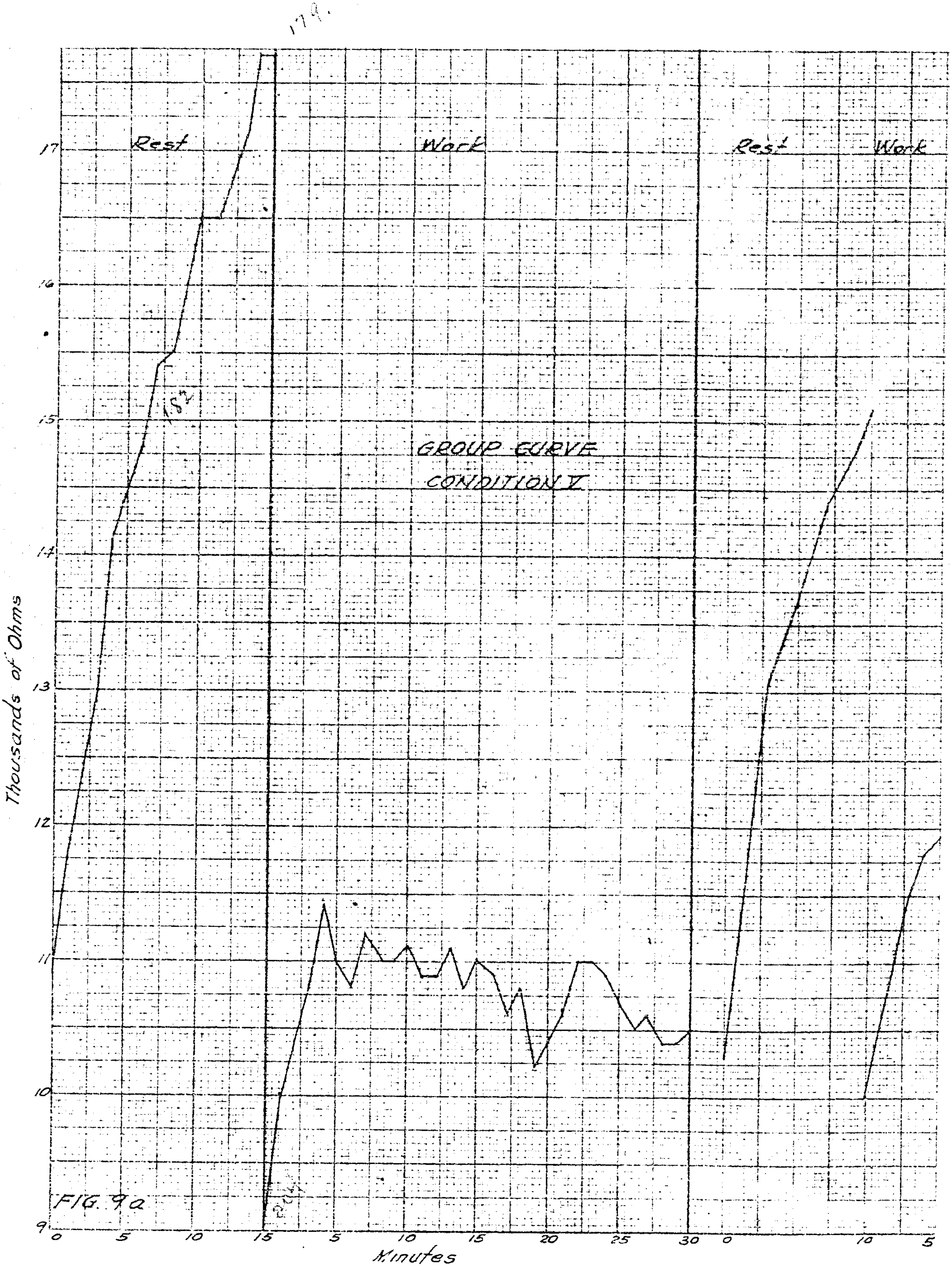


Rest
Work
Rest
Work
GROUP CURVE
CONDITION III
FIG 7 a
Thousands of Ohms
Minutes
9
10
11
12
13
14
15
16
17
18
5
10
15
5
10
15
20
25
30
0
5
0
5



26,188
Rest
Work
Rest
Work
GROUP CURVE
CONDITION IV
Thousands of Ohms
22
21
20
19
18
17
16
15
14
13
0
5
10
15
5
10
15
20
25
30
0
7
0
5
Minutes

FIG. 8a


179.
Rest
Work
Rest
Work
182
GROUP CURVE
CONDITION V
Thousands of Ohms
17
16
15
14
13
12
11
10
9
FIG. 9a
0
5
10
15
5
10
15
20
25
30
0
10
5
Minutes

It will be recalled that the subjects were instructed to relax completely, both physically and mentally, during both the pre-work and post-work rest periods. They sat in a comfortable chair with eyes closed and were urged to go to sleep if possible. They were to change the original position only in case of discomfort. That is to say, it was strongly impressed on all subjects that rest meant "relatively minimum reactivity level". But the experimenter's record of changes in observed behavior, concurrent with sudden galvanic deflections, carried notations like the following: "lifted head, crossed leg, sighed, took a deep breath, noise in hall, noon factory whistle, was restless, couldn't relax, admittedly reminiscing". Thus, in spite of the most diligent effort, some few individuals relaxed control, or unavoidable distractions occurred in the more remote environment.

General Characteristics of Resistance Curves of Work - The outstanding point of contrast of the work curves with the rest curves is their extreme irregularity. The prolonged variation in resistance is interrupted repeatedly by sudden transitory deflections.

With the exception of an initial rapid rise in resistance occurring during the first three to five minutes of work, the resistance work curves are not uniform in shape. Seventy-five per cent of the individual curves and the group curves for Conditions I, III, IV and VI may be characterized as follows: an initial rapid rise during the first three to five minutes followed by a more gradual increase in resistance to between the eighteenth and twenty-third minutes, and then a gradual decline. The curve for Condition II deviates from this general pattern only after the twenty-second minute, with a continued rise instead of a fall. After the initial rise, the curve for Condition V, however, declines gradually to the end of the work period. Examination of the eight individual curves for this condition reveals a radical decline after initial resistance for curve 9f and a more gradual decline for curve 9b. Because of the small number of cases, the group average was unduly affected by the radical changes represented by these two curves.

Resistance Levels for Curves of Rest versus Curves of Work - All pre-work rest curves attain levels of relatively high resistance. With the exception of the two-minute period, the same is true, in general, of post-work rest curves. In sharp contrast to the high resistance of the relaxation periods are the relatively low resistance levels demonstrated by the curves of work. These observations are supported by the facts in Tables XV and XVI. Table XV presents the range in initial and final resistance levels for the preliminary rest periods of each of the six conditions. In Table XVI are found the range in resistance for the lowest and highest points of the six continuous work periods. These findings are confirmed by the researches of Richter and Darrow. Both investigators associate conditions approximating relaxation and sleep with very high resistance. On the other hand, according to Darrow particularly, the more apprehensive and attentive a person is, the lower the level of palmar skin resistance.

Summary Statement - In summary, let it be emphasized that the state of relatively minimum reactivity level was reflected in curves showing a progressive increase in resistance with successive units of time. The curves presented, also, prolonged variations in resistance with few sudden transitory changes. They attained in addition very high

TABLE XV

RANGE IN INITIAL AND FINAL RESISTANCE LEVELS FOR THE PRELIMINARY REST PERIOD FOR EACH OF THE SIX CONDITIONS

Condition	Range in Ohms in Initial Level	Range in Ohms in Final Level
I - 2 Minutes	7900 - 16500	10855 - 29025
II - 3 Minutes	8600 - 14900	9360 - 30550
III - 5 Minutes	5600 - 25900	8075 - 31170
IV - 7 Minutes	8500 - 25900	12660 - 59100
V - 10 Minutes	8100 - 14800	11800 - 31900
VI - 20 Minutes	8900 - 36900	8900 - 47560

TABLE XVI

RANGE IN RESISTANCE LEVELS AT LOWEST AND HIGHEST POINTS OF CONTINUOUS WORK PERIOD FOR EACH OF THE SIX CONDITIONS

Condition	Lowest Point of Curve	Highest Point of Curve
I - 2 Minutes	7900 - 10600	9490 - 13750
II - 3 Minutes	8600 - 11900	10880 - 17900
III - 5 Minutes	5600 - 12900	8090 - 20380
IV - 7 Minutes	8900 - 20900	10000 - 29000
V - 10 Minutes	5850 - 110700	8285 - 15070
VI - 20 Minutes	8080 - 15500	9390 - 18840

levels of resistance.

In sharp contrast, continuous work performance was reflected by curves representing relatively low resistance levels and characterized by numerous sudden galvanic deflections.

Resistance Work Curves versus Output Work Curves - It will be recalled that in general the curves of skin resistance changes during continuous mental work showed an initial rapid rise up to the fourth or fifth minute, followed by a gradual rise and then a decline. In comparison, the output curve for continuous work was characterized, in the main, by an early rise during the first three or four minutes, followed by a shallow depression. Beginning between the fourteenth and twentieth minute, a gradual increment in output continues to the end of the curve.

Before attempting to reconcile the spurt in the output curve with that in the resistance curve, attention is directed to Table XVII. The facts in the table indicate that a drop in resistance ranging from 7500 to 13000 ohms occurred during the shift from rest to working conditions. To begin the task, it was obviously necessary for the subjects to change from a resting to a working position. While the shift in position was being made, the incentive was also repeated. Thus, the changing behavior pattern involved not only sudden bodily movements, but also increased alertness, apprehension, and anxiety. Schubert reports for physical exercise, that the greatest part of the oxygen debt is accumulated in transition from rest to working condition. Schaeffer found drops in resistance accompanying movements and, according to Darrow, the more apprehensive and attentive a person is, the lower his palmar resistance.

The early rise in the output curve suggests persistence of

TABLE XVII

AVERAGE DROP IN RESISTANCE FROM FINAL POINT ON PRE-WORK REST CURVE TO INITIAL POINT ON WORK CURVE FOR SIX CONDITIONS

Condition	Final Point on Preliminary Rest Curve	Initial Point on Work Curve	Change
I - 2 Minutes	16709	9200	7509
II - 3 Minutes	18700	10200	8500
III - 5 Minutes	18400	9200	9200
IV - 7 Minutes	26200	13200	13000
V - 10 Minutes	17520	9100	8420
VI - 20 Minutes	21260	11500	10760

increased alertness. Among the explanations offered for early rise in output are those given in terms of motivation, assumption of too rapid a working pace and a high degree of initial concentration of attention. According to Freeman, effort to work above the congenial pace is accompanied by increased performance and decreased palmar resistance. As has been stated, according to Darrow, increase in apprehension and attention are associated with decrease in the level of palmar resistance. Yet, despite the expectation of a drop in resistance during the beginning of continuous work, a sufficient rise, due to other causes occurred to obscure this expected drop.

Attention has already been called to the marked loss in resistance reflected by the gross bodily movements and increased alertness involved in the shift from rest to work. Evidence for persistence of the increased alertness after beginning work was also given, but no mention of the resistance recovery curve from the gross bodily movements has been made. While the amplitude and duration of this recovery curve cannot be supported by quantitative facts from this investigation, that it will show a rise in resistance may be safely assumed. Freeman and Simpson, who had subjects make a quick thrust on levers (scale value 100) followed by a quick release, found a 5000 ohm drop. They stated further that the recovery curve for the palmar response was regular and tended to return within four minutes to the level established prior to the quick thrust.

It seems that mere occurrence of initial rise in the resistance work curve may be safely attributed to recovery from the gross bodily movements described. But the fact that the amplitude of the initial rise (average 1700 ohms) was so small should be considered as determined by the counter effect of the apprehension and alertness caused by the mental work.

Following the progress of the two sets of curves, there will be observed, an apparent increase in resistance as mental work efficiency decreases. This pattern follows the initial rise and continues to a point between the fourteenth and eighteenth minute depending upon the condition concerned. A decrease in subjective feeling-tone paralleled the decrease in output and increase in resistance. In general then, a positive relationship between the three aspects of fatigue was suggested by the foregoing three tendencies. It will be remembered that, during the relaxation period, a progressive decrease in general reactivity was reflected by a progressive increase in resistance. In this portion of the work curve, a relatively lower reactivity (decrement in output) is reflected by increased resistance and a decrease in the feeling of fitness for work. (See Table XVIII). In line with the foregoing skin resistance trend, the reports of Darrow, and Darrow and Freeman suggest that the different skin areas represent largely differences in the ease of excitation, with the palm becoming more active first and dropping toward its limit of physiological reactivity as the non-palmar areas become increasingly responsive.

The increase in prolonged resistance was punctuated by numerous deep fluctuations. For many of these, the experimenter's running commentary reads: "squirmed, moved closer to board, punched violently, crossed legs, placed hand on head, muttered, commented, etc." In fact, the observable behavior of most subjects presented a continuous repetition of such movements. In addition, many blocks in comprehension also occurred practically simultaneously with the deep fluctuations. These fluctuations

TABLE XVIII

TOTAL FEELING-TONE VALUES GIVEN AT THE END OF EACH FIVE MINUTES OF WORK

FOR THE SIX CONDITIONS

Condition	Check Before Work	Thirty Minutes of Work						Check Immediately-after Rest	Check the Next Day
		1st 5 Min.	2nd 5 Min.	3rd 5 Min.	4th 5 Min.	5th 5 Min.	6th 5 Min.		
I	217	210	207	203	196	200	198	202	217
II	215	206	203	202	197	192	191	204	217
III	207	207	196	194	197	196	191	203	213
IV	217	208	203	205	196	188	184	213	220
V	209	204	201	190	194	193	190	193	214
VI	212	208	210	203	203	195	197	192	210
Total	1277	1243	1220	1197	1183	1164	1151	1207	1291
Average	213	207	203	199	197	194	192	201	215

in the galvanic curve must be in some way related to the processes occurring during the mental work performance because they were not consistently present in either the pre-work or post-work rest curves. The least that can be said about these fluctuations is that they indicate a relatively higher general reactivity level than was manifested during rest. The blocks, according to Bills, are compensatory mechanisms. He maintains that, they represent a period of lowered activity capacity which recurs at frequent intervals and serves a recuperative function.

Returning again to the comparison of the two sets of curves, it will be observed that the increment in output during the last fifteen to nineteen minutes of the continuous work curve is accompanied by a drop in the resistance curve. The declining trend of the resistance curves is punctuated by the deep fluctuations accompanied by postural shifts. Although the decrease in subjective feeling-tone continues, this decrease is only 50 per cent of that of the preceding period. In view of the declining resistence, this appears to be the picture of a more alert, active organism than that described in the previous part of the continuous work period. But external stimulation has been constant, no augmentation has taken place. There is a possibility that the change in stimulus strength was a function of the internal stimuli suggested by Dodge. A number of possibilities in this catagory suggest themselves. The organism under a constant competitive set or a set to maintain a certain ideal of efficiency, was spurred to extra effort by awareness of the preceding deficiency. Or the subject may have been goaded on by the hope of the ten-dollar reward, by stubbornness, or by dislike for failure. Again, the feeling of success, of confidence, due to the familiarity of the now practiced task may have had a facilitative effect. But Dodge emphasizes the fact that renewed command of the motor apparatus or the change in attitude toward the work and any other internal reinforcements are compensatory mechanisms for real fatigue. Another word of caution must be sounded at this point. The reinforcement suggested by the foregoing stimuli appears to be, according to Freeman, chiefly automatic. He says, "Subjects do not usually attempt to reinforce by any voluntary contraction of any part of the musculature or by increase in restlessness, etc."

Relationship between Recovery in Skin Resistance and Objective and Subjective Recovery - It will be recalled that up to this point in the experimental procedure, all influencing factors were held constant for the six groups. It was not until the termination of the continuous work period that the manipulated variable was introduced. Each group of subjects was accordingly allowed a rest period of a different length. Let it be emphasized again, that rest in this investigation implies relaxation of the musculature and inhibition of all mental activity as far as possible. Subjects sat comfortably with eyes closed and were urged to fall asleep.

Examination of the post-work recovery curves reveals a disappearance of the pattern so prominent at the end of the continuous work period. The lowered resistance and the deep fluctuations have been replaced by a rising resistance free, in general, of sudden transitory changes.

Quantitative gains in resistance level for each of the eight subjects under the six conditions have been represented in Tables XIX through XXIV. The facts in the tables and the shape of the curve reveal a positive relationship between increase in resistance and the passage of time. This relationship is shown graphically in the curve in Figure 2d.

<u>Summary Statement</u> - For convenient comparison, the recovery ratios for the three aspects of recovery from mental fatigue were brought together in Table XXV. The facts in the table show a negatively accelerated rate of recovery up to the seventh minute for all aspects of fatigue. From this point on, there is shown negative relationship between skin resistance changes and performance changes. For example, after twenty minutes of rest the percentage of increase in skin resistance is approximately twice that after the ten minute rest. For objective recovery, the twenty minute recovery ratio is less than the ten minute ratio. That is to say, whereas a certain degree of relaxation facilitates subsequent performance, too high a degree inhibits performance. Freeman found an optimal amount of muscular tension for facilitation of performance. More or less than this amount had a detrimental effect.

Reference to Table XXV reveals that, from seven minutes on, objective and subjective recovery cease to be interdependent. A decline from 84 per cent to 53 per cent in the objective rate for the ten minute period was shown in comparison with a drop from 80 per cent to 6 per cent in subjective rate. In addition, a decline in the objective rate from 84 per cent to 42 per cent for the twenty minute period is contrasted with a decline from 80 per cent to a minus 30 per cent in the subjective rate. That is to say, for the first seven minutes, the resting worker's attitude toward the resumption of work is favorable.

RECOVERY CURVE BASED ON RESISTANCE
CHANGES DURING REST PERIODS

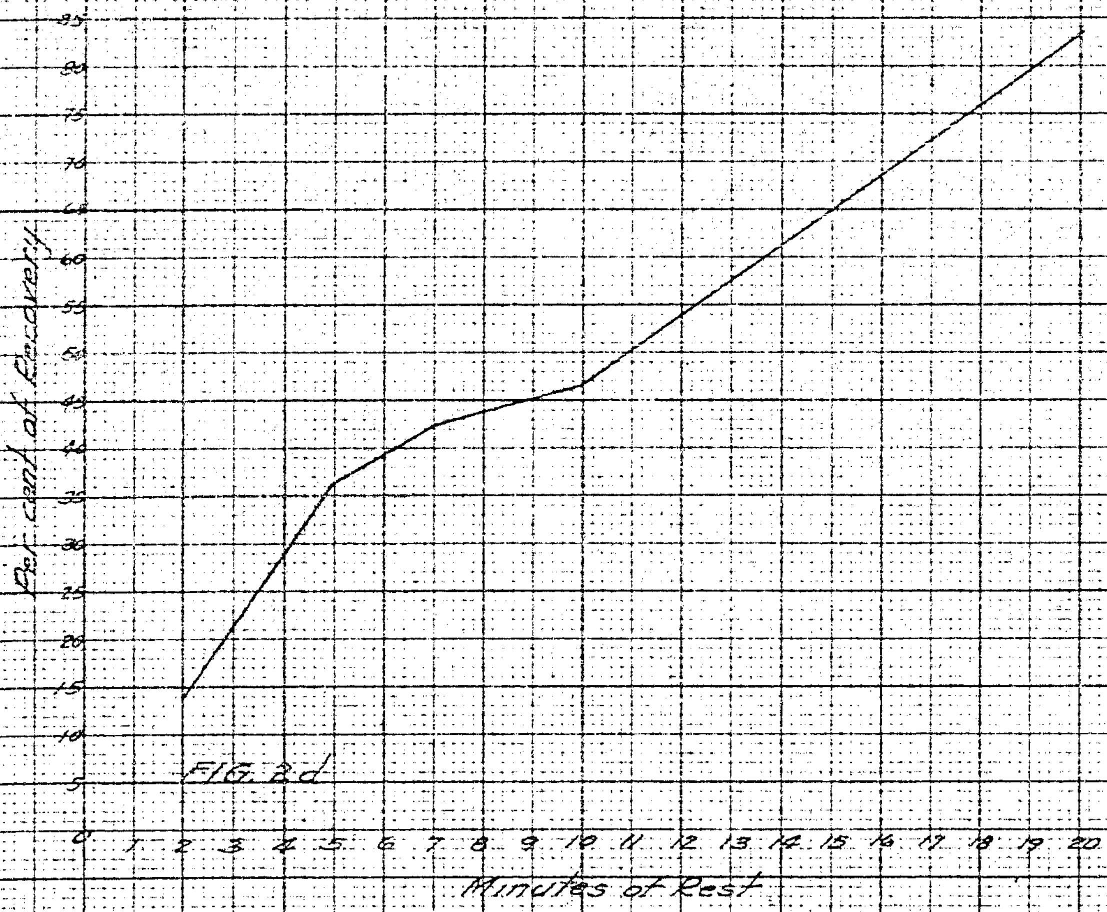


FIG. 2d

TABLE XIX

AVERAGE RESISTANCE CHANGES DURING REST FOR EACH SUBJECT OF CONDITION I

	I	II	III	IV
Subject	Beginning of Rest Period	End of Rest Period	Change Bet. I & II	Percent of Change
I A	7080	8900	1820	25.7
I B	7260	8080	820	11.3
I D	7320	9140	1820	24.9
I G	10700	12160	1460	13.6
I I	10340	9910	- 430	- 4.2
I P	8420	9240	820	9.7
I R	10820	12480	1660	15.3
I S	11440	13540	2100	18.4
Average	9173	10430	1257	14.3

TABLE XX

AVERAGE RESISTANCE CHANGES DURING REST FOR EACH SUBJECT OF CONDITION II

	I	II	III	IV
Subject	Beginning of Rest Period	End of Rest Period	Change Bet. I & II	Percent of Change
II J	10860	11520	660	6.1
II F	9900	12442	2542	25.7
II G	10540	11965	1425	13.5
II A	16080	20180	4100	25.5
II L	7680	10420	2740	35.7
II N	12840	17660	4820	37.5
II R	12740	14560	1820	14.3
II T	14020	15340	1320	9.4
Average	11820	14261	2441	20.9

TABLE XXI

AVERAGE RESISTANCE CHANGES DURING REST FOR EACH SUBJECT OF CONDITION III

	I	II	III	IV
Subject	Beginning of Rest Period	End of Rest Period	Change Bet. I & II	Percent of Change
III G	8900	11330	2430	27.3
III H	11110	15550	4440	40.0
III I	10060	12035	1975	19.6
III M	8080	9505	1425	17.6
III V	8900	11690	2790	31.3
III W	8900	13285	4385	48.9
III U	9160	17055	7895	86.2
III R	12700	16260	3560	28.0
Average	9726	13214	3488	36.1

TABLE XXII

AVERAGE RESISTANCE CHANGES DURING REST FOR EACH SUBJECT OF CONDITION IV

	I	II	III	IV
Subject	Beginning of Rest Period	End of Rest Period	Change Bet. I & II	Percent of Change
IV G	11885	16325	4440	37.3
IV I	8545	14875	6330	74.1
IV J	13540	16550	3010	22.2
IV K	8500	10785	2285	26.8
IV M	20900	26820	5920	28.3
IV W	.8740	23380	4640	24.8
IV X	9760	17180	7420	76.0
IV V	21000	31195	10195	48.5
Average	14109	19640	5531	42.3

TABLE XXIII

AVERAGE RESISTANCE CHANGES DURING REST FOR EACH SUBJECT OF CONDITION V

	I	II	III	IV
Subject	Beginning of Rest Period	End of Rest Period	Change Bet. I & II	Percent of Change
V L	8180	9725	1545	18.9
V K	9300	11100	1800	19.4
V H	7300	11700	4400	60.3
V F	8500	12600	4100	48.2
V E	10500	15700	5200	49.5
V D	13380	22300	8920	66.7
V P	13500	17265	3765	27.9
V T	11800	21500	9700	82.2
Average	10308	15240	4932	46.6

TABLE XXIV

AVERAGE RESISTANCE CHANGES DURING REST FOR EACH SUBJECT OF CONDITION VI

	I	II	III	IV
Subject	Beginning of Rest Period	End of Rest Period	Change Bet. I & II	Percent of Change
VI H	9100	17400	8300	91.2
VI M	12440	22600	10160	81.7
VI N	8860	20300	11440	129.1
VI Q	14400	21300	6900	47.9
VI U	16800	25540	8740	52.0
VI X	14800	27700	12900	87.2
VI Y	12000	26300	14300	119.2
VI K	8900	14300	5400	60.7
Average	12162	21930	9768	83.6

TABLE XXV

RECOVERY RATIOS FOR THE THREE ASPECTS OF FATIGUE

Condition	Objective Recovery			Subjective Recovery	Recovery in Terms of Skin Resistance Changes
	Problems Completed	Problems Worked Correctly	Blocking		
I	36.78	37.70	16.6	19.0	14.3
II	62.032	65.25	37.5	50.0	20.9
III	72.86	79.26	63.6	55.0	36.1
IV	84.77	86.30	66.6	80.0	42.3
V	53.27	54.90	25.0	8.0	46.6
VI	42.06	44.47	12.5	-30.0	83.6

After a rest of ten minutes or more, the desire for work has practically left him entirely. By the end of twenty minutes, some subjects even expressed distaste for resumption of the task.

Summary and Conclusions

The recovery effects of variable rest intervals which are presented in outline form below, it must be emphasized, were functions of relatively complete physical and mental relaxation, following thirty minutes of continuous work.

1. The form of the recovery curve for the three criteria of objective fatigue, namely, problems completed, problems worked correctly and number of blocks was sinusoidal in character. That is to say, the third degree regression equation provided the line of best fit. The optimal rest period, as indicated by the empirical curve, occurred after seven minutes of rest, with less efficiency shown after ten and twenty minutes than after three and five. Determination of the course of recovery between the ten and twenty-minute rest intervals is suggested as a supplementary study.

2. The recovery curve for subjective feeling-tone follows the same general pattern as that for objective output. However, the drop after seven minutes, which again is the optimal rest period, is more pronounced for the former than for the latter curve.

3. After seven minutes of rest, the recovery curve for skin resistance continues to rise in contrast with the drop of the curves for the other two aspects of fatigue.

4. The foregoing findings suggest the conclusion that a certain degree of relaxation facilitates subsequent performance, whereas, too high a degree inhibits performance.

Among the problems related to these findings suggested for future research are: First, the recovery effects of rest periods spent in free conversation, partaking of refreshments, moving about, reading, etc.; second, the determination of the recovery curve for varying types of imposed tasks; and third, the determination of the form of the curve of recovery for tasks of varying lengths.

Discussion and Interpretation

It was pointed out in the foregoing, that the sinusoidal curve, or graphical representation of the third degree regression equation, was demonstrated to be an qdequate fit for the empirically derived curve of objective recovery. For the empirical curve, a sharp rise, at a negatively accelerated rate, to an optimal recovery period at seven minutes is followed by a decline, at ten and twenty minutes. The course of relative changes in skin resistance levels follows the same general pattern up to seven minutes only. From this point on, the curve continues to rise in contrast with the drop of the output curve.

The results of this investigation are interpreted according to Darrow's theory that the changes in skin conductance indicate corresponding changes in bodily tension. In recent reviews of the literature, Darrow has suggested "that the increased palmar sweating observed to follow extirpation of the pre-motor cortex may not be so much a direct release of autonomic centers from inhibitory restraints, as a secondary result from stimulation of these centers by heightened impulses from released centers of tonic postural control". He then sets forth the hypothesis that impulses to the sweat glands fall into three general classes:

(a) those with parasympathetic effects; (b) those with sympathetic effects; and (c) those which represent a combination in varying proportion of types a and b. He further states that the parasympathetic effects and the sympathetic effects apparently do not neutralize one another as is the case of other autonomic structures. He concludes, then, that such a fact would "possibly account for the unique significance of palmar sweating as an index of general preparatory and facilitative bodily processes". Freeman provides results which lend support to this general position and which suggest that, "under careful experimental controls, the palmar skin resistance may be used to measure the degree of general arousal of the autonomic-postural substrate". More specifically, he found that the palmar changes tend to vary directly with changes in muscular tension. That is to say, resistance decreased with increasing tension and increased with decreasing tension. In an earlier experiment, Freeman provides evidence from which he concludes that variability in performance, restlessness and tonus increase with the duration of work. High variability and increased neuro-muscular activity characterize the initiation of poorly adapted performance. Freeman relates his results to the laws of relative fatigue which include: "First, the relative loss of control of the directive set over the behavior flux; and second, the reinforcement probably active to balance the competition of incompatible reaction tendencies". The importance of reinforcement is stressed.

The rise of all post-work resistance recovery curves, obtained in this investigation suggests, accordingly, gradual release from the relatively high degree of neuro-muscular activity and apprehension prevailing at the end of the continuous work period. The deep fluctuations which punctuated the general course of the curve of continuous work and which occurred simultaneously with changes in postural shifts were also absent. Their absence lends confirmation to the hypothesis that such release is occurring.

To the extent that increasing resistance reflects decreasing tension, there appears to be an optimal tension which results in maximal output. This stage apparently occurred after seven minutes of rest in the present investigation. Further decrease in tension which occurred with longer periods of rest resulted in decreased efficiency. For example, the per cent of manifested recovery was less after ten and twenty minutes of rest than after seven minutes.

Freeman and Stauffacher have demonstrated the relationship between optimal tension and maximal output. Freeman offers a rather plausible explanation of the way in which muscular tonus operates in producing an effect upon the mental processes. He assumes that cortical centers involved in mental work have high thresholds. When these thresholds are lowered, the centers will react to stimuli which would otherwise be inadequate. This is accomplished by the spread of proprioceptive impulses which travel to the cortex from lower centers, especially those involved in muscular contraction. If this proprioceptive stimulation falls below a minimum level, cortical neurones become incapable of adequate response. Above a certain maximum, tension becomes an inhibitor of precise neural integration. The facilitative effect is only within limits. The inhibitory effects of tension are of two kinds: (a) decreased efficiency with decreased tension; and (b) decreased efficiency with increased tension.

The form of the subjective recovery curve indicates an optimal point in readiness to resume the task after a prolonged rest. This also occurs after seven minutes of rest. From this point on, there is a drop in readiness.

Graf reported that the worker's willingness to resume work undergoes a series of changes during the rest period. He found the worker's attitude was favorable for the first five or ten minutes. Then there was a decline in readiness followed by an ultimate rise.

The foregoing results provide another possible index as to the course of the probable influence of the "work-set" upon the subsequent "rest-set". Apparently, the release from the excessive strains felt at the end of the work period is welcomed by the worker. The interruption of the "work-set" is acceptable up to the point when inception of voluntary effort will not be painful. The postural substrate of the "work-set" may have declined to its optimum tension by this time. Gradual continuous lowering of these tensions weakens the traces of the "work-set" and strengthens the "rest-set". As the "work-set" tensions become lower, inception of voluntary effort becomes more unpleasant to the worker. In this investigation the worker's distaste for the resumption of the task apparently increased more rapidly than the "work-set" tensions decreased.

It must be emphasized that the foregoing interpretation is intended only for rest periods spent in relatively complete relaxation. The "work-set" residua might have had a different influence on the rest pause effects if free conversation, reading, moving about, smoking, and partaking of refreshments had been introduced. Such changes in occupation might have provided freedom from the restraint imposed upon the organism during complete relaxation. Resistance to such restraint as was imposed by the instructions given in this experiment may not only have had an inhibitory effect upon performance for the longer periods of rest, but may have retarded recovery during the shorter periods. Here is a problem for future research.

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APPENDIX A

1. Summary Tables for Conditions I, II, III, IV, V, and VI
2. Recovery Ratios for Each Individual for Problems Worked Correctly
3. Averages, Standard Deviations, Standard Errors, and Critical Ratios for Total Number of Problems Worked Correctly for Six Different Groups
4. Figure Analogies
5. Instructions for Working Analogies
6. Feeling-tone Rating Scales
7. Instructions for Marking Rating Scales
8. Resistance Curves for Two Subjects of Each Group

TABLE I - NUMBER OF PROBLEMS COMPLETED DURING EACH

Subject	Thirty-Minute Work P																			
IA	3	3	4	5	4	19	4	2	4	3	5	18	4	4	2	6	6	22	3	5	
IB	8	7	6	8	7	36	8	7	8	7	6	36	8	8	8	5	9	38	7	8	
IC	5	4	6	7	7	29	3	4	8	7	7	29	6	7	7	9	8	37	9	8	
ID	4	1	3	2	5	15	4	1	2	0	3	10	2	2	2	3	1	10	2	1	
IE	5	5	7	5	7	29	7	8	2	6	4	27	6	6	5	7	9	33	4	7	
IF	4	2	3	4	5	18	1	2	4	4	6	17	1	5	3	3	2	14	5	4	
IG	7	7	10	9	8	41	6	7	9	9	7	38	9	8	10	8	6	41	7	8	
IH	8	8	7	10	10	43	4	8	7	3	5	27	8	8	9	9	10	44	8	7	
II	6	3	8	5	4	26	5	3	8	5	4	25	6	5	2	7	4	24	3	8	
IJ	7	8	6	8	6	35	1	2	4	5	3	15	5	4	5	5	3	22	4	3	
IK	6	7	7	7	4	31	5	5	6	4	7	27	5	6	6	6	7	30	5	8	
IL	5	5	6	4	4	24	4	3	3	5	5	20	4	2	7	2	1	16	2	5	
IM	5	6	3	8	6	28	6	6	4	5	4	25	5	5	4	8	5	27	5	5	
IN	3	4	4	7	6	24	6	5	3	5	5	24	3	4	4	4	4	19	3	4	
IO	3	4	3	4	6	20	3	4	3	4	5	19	3	3	3	5	5	19	3	4	
IP	4	2	4	5	6	21	4	3	4	7	4	22	2	4	4	4	4	18	3	8	
IQ	2	4	6	4	3	19	3	6	4	2	6	21	3	3	5	6	2	19	2	5	
IR	4	5	5	5	3	22	5	3	4	1	4	17	4	3	2	5	2	16	2	2	
IS	5	5	6	5	5	26	5	5	6	5	6	27	5	4	5	5	5	24	6	6	
IT	4	4	4	6	3	21	4	5	1	5	7	22	4	1	1	6	6	18	6	4	
IU	8	8	7	6	6	35	7	5	6	7	4	29	4	6	5	6	8	29	6	5	
IV	5	4	7	7	2	25	6	6	4	6	6	28	4	2	6	3	5	20	4	7	
IW	7	10	3	7	6	33	3	6	4	4	6	23	4	8	6	5	7	30	9	8	
IX	5	4	5	6	8	28	3	7	7	4	6	27	6	6	5	4	6	27	8	8	
IY	7	4	6	5	4	26	7	7	5	7	3	29	5	5	7	6	7	30	6	5	
Total	130	124	136	149	135	674	114	120	120	120	128	602	116	119	123	137	132	627	122	143	14
Av. per Minute	5.2	4.9	5.4	5.9	5.4	26.9	4.6	4.8	4.8	4.8	5.1	24.1	4.5	4.8	4.9	5.5	5.3	25.1	4.8	5.7	5.

G EACH MINUTE OF THREE WORK PERIODS FOR EACH SUBJECT OF CONDITION I

Work Period																		Test Immediately after Rest						
5	6	7	6	27	7	2	5	6	6	26	7	6	5	4	6	28	7	9	5	6	8	35	10
8	6	9	8	38	8	6	6	7	8	35	7	9	8	7	8	39	10	8	8	9	11	46	13
8	9	7	8	41	7	8	10	7	9	41	8	10	9	12	7	46	11	11	9	11	13	55	13
1	2	4	1	10	2	2	4	5	3	16	1	4	1	2	4	12	2	6	6	4	7	25	7
7	7	6	7	31	7	10	8	8	7	40	9	9	5	8	8	39	7	5	9	8	9	38	10
4	4	0	3	16	3	2	6	5	7	23	4	5	6	5	7	27	9	7	9	6	5	36	10
8	8	10	6	39	11	7	8	7	5	38	6	9	8	7	11	41	14	12	14	8	11	59	14
7	9	8	8	40	11	8	9	8	9	45	10	10	11	7	10	48	9	9	8	11	9	46	11
8	9	6	7	33	6	7	6	7	10	36	8	6	8	7	8	37	8	7	10	6	9	40	11
3	7	2	4	20	4	6	5	4	4	23	5	5	5	3	7	25	5	7	6	5	7	30	5
8	7	8	7	35	6	4	8	9	10	37	7	7	8	8	7	37	10	11	8	9	10	48	10
5	2	3	3	15	4	4	3	6	6	23	3	3	5	6	2	19	8	2	4	4	2	20	4
5	5	7	6	28	5	6	4	5	6	26	6	8	8	5	8	35	9	6	9	7	8	39	8
4	4	8	10	29	4	8	7	9	7	35	6	7	5	7	5	30	6	5	8	9	5	33	11
4	4	4	3	18	4	5	5	6	4	24	4	4	6	4	4	22	5	5	6	6	7	29	4
8	7	10	9	37	4	6	3	5	4	22	6	3	6	4	3	22	7	6	3	6	6	28	4
5	3	7	2	19	2	4	6	6	4	22	4	3	2	7	8	24	4	4	5	4	7	24	6
2	2	2	2	10	3	4	2	3	2	14	4	5	5	3	5	22	5	4	4	3	5	21	6
6	6	6	6	30	5	4	6	6	4	25	7	3	5	5	5	25	4	5	7	6	7	29	9
4	4	4	7	25	5	10	6	6	6	33	6	6	4	5	7	28	8	6	7	8	9	38	8
5	7	7	6	31	7	6	6	6	6	31	6	5	6	5	6	28	8	6	6	8	7	35	7
7	7	6	6	30	7	7	5	7	4	30	7	5	9	7	8	36	10	7	8	7	8	40	10
8	5	8	9	39	7	7	5	5	9	33	6	9	8	8	6	37	7	10	9	10	5	41	11
8	6	7	7	36	8	5	10	6	8	37	6	7	8	8	7	36	9	6	7	7	6	35	8
5	5	4	7	27	7	7	8	8	9	37	7	5	8	6	7	33	8	7	9	8	6	38	9
143	141	150	148	704	144	145	149	157	157	752	150	153	159	150	164	776	190	171	184	176	187	908	219
5.7	5.6	6.0	5.9	28.2	5.7	5.7	5.7	6.2	6.2	30.1	6.0	6.1	6.3	6.0	6.5	31.0	7.6	6.8	7.3	7.0	7.5	36.3	8.7

RIODS FOR EACH SUBJECT OF CONDITION I

										Test Immediately after Rest						Test the Next Day					
5	6	6	26	7	6	5	4	6	28	7	9	5	6	8	35	10	7	8	7	9	41
6	7	8	35	7	9	8	7	8	39	10	8	8	9	11	46	13	9	11	12	9	54
10	7	9	41	8	10	9	12	7	46	11	11	9	11	13	55	13	12	13	12	11	61
4	5	3	16	1	4	1	2	4	12	2	6	6	4	7	25	7	7	6	7	7	34
8	8	7	40	9	9	5	8	8	39	7	5	9	8	9	38	10	11	11	9	9	50
6	5	7	23	4	5	6	5	7	27	9	7	9	6	5	36	10	10	8	10	9	47
8	7	5	38	6	9	6	7	11	41	14	12	14	8	11	59	14	12	12	10	14	62
9	8	9	45	10	10	11	7	10	48	9	9	8	11	9	46	11	11	12	12	12	58
6	7	10	36	8	6	8	7	8	37	8	7	10	6	9	40	11	10	8	12	9	50
5	4	4	23	5	5	5	3	7	25	5	7	6	5	7	30	5	8	9	8	10	40
8	9	10	37	7	7	8	8	7	37	10	11	8	9	10	48	10	11	13	11	12	57
3	6	6	23	3	3	5	6	2	19	8	2	4	4	2	20	4	8	6	4	3	25
4	5	6	26	6	6	8	5	8	35	9	6	9	7	8	39	8	7	9	7	10	41
7	9	7	35	6	7	5	7	5	30	6	5	8	9	5	33	11	9	10	10	9	49
5	6	4	24	4	4	6	4	4	22	5	5	6	6	7	29	4	7	7	5	8	31
3	5	4	22	6	3	6	4	3	22	7	6	3	6	6	28	4	6	8	7	7	32
6	6	4	22	4	3	2	7	8	24	4	4	5	4	7	24	6	3	7	7	8	31
2	3	2	14	4	5	5	3	5	22	5	4	4	3	5	21	6	7	4	6	7	30
6	6	4	25	7	3	5	5	5	25	4	5	7	6	7	29	9	8	6	8	9	40
6	6	6	33	6	6	4	5	7	28	8	6	7	8	9	38	8	8	8	11	8	43
6	6	6	31	6	5	6	5	6	28	8	6	6	8	7	35	7	9	7	8	9	40
5	7	4	30	7	5	9	7	8	36	10	7	8	7	8	40	10	10	9	10	8	47
5	5	9	33	6	9	8	8	6	37	7	10	9	10	5	41	11	11	8	8	9	47
10	6	8	37	6	7	8	8	7	36	9	6	7	7	6	35	8	8	11	8	10	45
6	8	9	37	7	5	8	6	7	33	8	7	9	8	6	38	9	8	9	9	9	44
49	157	157	752	150	153	159	150	164	776	190	171	184	176	187	908	219	217	220	218	225	1099
.7	6.2	6.2	30.1	6.0	6.1	6.3	6.0	6.5	31.0	7.6	6.8	7.3	7.0	7.5	36.3	8.7	8.7	8.8	8.7	9.0	43.9

TABLE II - NUMBER OF PROBLEMS COMPLETED DURING EA

Subject	Thirty-minute Work																				
II A	5	4	6	6	4	25	6	5	7	5	6	29	5	6	4	5	4	24	5	4	
II B	5	4	5	5	2	21	5	6	4	5	5	25	4	9	4	5	5	27	5	6	
II C	4	3	3	5	4	19	3	3	3	3	4	16	4	6	3	2	5	20	3	5	
II D	4	5	7	6	5	27	6	7	5	5	9	32	8	8	5	7	8	36	7	5	1
II E	5	6	6	5	5	27	7	9	7	9	7	39	8	10	11	9	4	42	7	7	
II F	5	5	11	7	6	34	7	6	4	7	6	30	8	4	5	7	8	32	8	7	
II G	2	3	1	4	3	13	5	2	4	2	3	16	3	1	3	2	4	13	1	3	
II H	4	3	3	2	3	15	2	2	4	2	2	12	2	3	2	3	2	12	3	2	
II I	4	3	3	6	4	20	4	4	5	4	6	23	4	3	5	2	2	16	4	5	
II J	6	4	6	4	5	25	5	4	6	7	4	26	6	4	5	4	4	23	4	7	
II K	4	5	4	5	1	19	1	4	6	4	4	19	3	2	3	1	3	12	3	2	
II L	7	6	8	6	6	33	6	6	2	6	7	27	7	8	6	7	9	37	9	6	1
II M	9	10	8	6	4	37	7	5	8	8	8	36	4	7	11	9	6	37	9	9	
II N	8	10	7	5	8	38	7	8	7	8	10	40	7	9	7	9	8	40	7	4	1
II O	5	3	5	6	4	23	4	4	3	6	4	21	4	4	5	4	5	22	5	4	
II P	8	7	7	7	7	36	5	5	3	9	8	30	4	5	6	6	6	27	8	8	
II Q	2	3	4	2	5	16	3	2	1	3	4	13	4	1	2	3	4	14	3	2	
II R	4	4	7	7	6	28	6	6	6	4	6	28	4	7	5	7	7	30	5	7	
II S	5	1	5	6	3	20	5	4	5	5	3	22	4	5	6	4	5	24	4	6	
II T	6	5	4	7	6	28	5	5	6	6	6	28	5	6	5	2	3	21	6	6	
II U	4	3	2	1	3	13	3	4	4	4	1	16	5	3	3	4	4	19	4	4	
II V	6	2	7	4	3	22	2	1	3	3	3	12	3	5	3	1	5	17	5	5	
II W	5	2	3	7	4	21	6	4	4	5	3	22	4	2	4	7	4	21	4	3	
II X	9	5	6	6	4	30	4	6	4	6	7	27	1	5	4	6	2	18	6	6	
II Y	10	6	9	7	8	40	6	5	6	4	6	27	6	5	5	6	5	27	4	6	
Total	136	112	137	132	115	630	120	117	117	130	132	616	117	128	122	122	122	611	129	129	14
Av. per Minute	5.4	4.5	5.8	5.3	4.5	25.2	4.8	4.7	4.7	5.2	5.3	24.6	4.7	5.1	4.9	4.9	4.9	24.4	5.2	5.2	5.

URING EACH MINUTE OF THREE WORK PERIODS FOR EACH SUBJECT OF CONDITION II

te Work Period																		Test Immediately after Rest						
5	4	7	5	4	25	3	6	8	7	4	28	5	6	3	6	6	26	6	8	7	8	9	38	
5	6	4	7	5	27	7	5	5	7	8	32	5	6	3	5	5	24	7	6	8	3	9	33	
3	5	3	4	2	17	6	3	3	5	5	22	2	6	5	4	5	22	4	4	5	5	6	24	
7	5	10	10	5	37	6	9	10	7	8	40	5	11	6	6	10	38	7	9	10	7	9	42	
7	7	7	7	6	34	11	11	11	11	9	53	10	10	12	12	9	53	9	12	14	11	14	60	
8	7	8	8	4	35	5	7	6	8	6	32	4	9	8	7	7	35	8	8	7	6	7	36	
1	3	2	4	3	13	3	4	3	3	1	14	4	1	3	5	3	16	6	3	6	4	5	24	
3	2	2	2	3	12	5	2	2	4	3	16	2	2	4	3	3	14	3	5	4	5	4	21	
4	5	4	5	5	23	7	3	5	5	4	24	7	4	5	5	5	26	6	6	3	9	6	30	
4	7	6	5	5	27	5	5	6	5	5	26	6	5	5	6	5	27	8	5	5	4	7	29	
3	2	2	3	3	13	4	4	3	2	5	18	5	8	5	7	5	30	5	7	6	5	8	31	
9	6	10	7	7	39	11	8	7	9	8	43	8	10	9	9	9	45	10	11	12	12	12	57	
9	9	9	9	9	45	8	9	9	10	8	44	11	9	9	8	11	48	12	10	13	9	13	57	
7	4	10	11	10	42	8	8	11	7	10	44	7	10	9	8	9	43	12	13	12	13	11	61	
5	4	4	4	5	22	6	4	3	5	7	25	4	6	5	4	6	25	6	8	6	8	7	35	
8	8	8	7	6	37	6	8	7	7	8	36	6	7	4	7	8	32	9	11	8	7	10	45	
3	2	2	3	2	12	3	3	1	3	3	13	2	2	4	3	4	15	4	6	3	5	4	22	
5	7	7	6	6	31	7	7	8	6	8	36	6	5	4	6	9	30	7	8	8	8	7	38	
4	6	6	6	7	29	6	8	7	7	7	35	7	7	7	8	5	34	6	9	8	10	10	43	
6	6	4	5	3	24	6	7	7	7	7	34	6	6	6	7	7	32	5	8	10	9	6	38	
4	4	6	7	3	24	4	4	4	5	4	21	5	4	4	5	6	24	7	6	9	7	8	37	
5	5	3	1	3	17	5	2	4	5	4	20	3	5	6	4	5	23	5	5	4	5	4	23	
4	3	5	5	2	19	4	7	3	7	3	24	4	6	6	7	2	25	8	8	8	7	6	37	
6	6	6	6	5	29	8	5	7	5	6	31	5	8	7	5	4	29	4	7	8	8	6	33	
4	6	7	4	6	27	5	5	7	7	5	29	5	5	5	6	4	25	7	6	7	6	6	32	
29	129	142	141	119	660	149	144	147	154	146	740	134	158	144	153	152	741	171	189	191	181	194	926	2
.2	5.2	5.7	5.6	4.8	26.4	5.9	5.8	5.9	6.2	5.9	29.6	5.4	6.3	5.8	6.1	6.1	29.6	6.8	7.6	7.6	7.2	7.8	37.0	8

K PERIODS FOR EACH SUBJECT OF CONDITION II

												Test Immediately after Rest						Test the Next Day					
6	8	7	4	28	5	6	3	6	6	26	6	8	7	8	9	38	10	10	11	10	11	52
5	5	7	8	32	5	6	3	5	5	24	7	6	8	3	9	33	10	8	9	11	9	47
5	3	5	5	22	2	6	5	4	5	22	4	4	5	5	6	24	6	8	4	5	5	28
9	10	7	8	40	5	11	8	6	10	38	7	9	10	7	9	42	12	11	11	11	9	54
1	11	11	9	53	10	10	12	12	9	53	9	12	14	11	14	60	13	13	10	15	11	62
7	6	8	6	32	4	9	8	7	7	35	8	8	7	6	7	36	8	9	11	9	10	47
4	3	3	1	14	4	1	3	5	3	16	6	3	6	4	5	24	5	2	5	5	7	24
2	2	4	3	16	2	2	4	3	3	14	3	5	4	5	4	21	4	4	6	4	5	23
5	5	5	4	24	7	4	5	5	5	26	6	6	3	9	6	30	8	6	8	9	7	38
5	6	5	5	26	6	5	5	6	5	27	8	5	5	4	7	29	8	8	6	6	6	34
4	3	2	5	18	5	8	5	7	5	30	5	7	6	5	8	31	8	8	6	9	10	41
8	7	9	8	43	8	10	9	9	9	45	10	11	12	12	12	57	12	11	12	13	8	56
9	9	10	8	44	11	9	9	8	11	48	12	10	13	9	13	57	14	14	11	14	12	65
8	11	7	10	44	7	10	9	8	9	43	12	13	12	13	11	61	15	15	14	14	12	70
4	3	5	7	25	4	6	5	4	6	25	6	8	6	8	7	35	4	7	5	6	8	30
8	7	7	8	36	6	7	4	7	8	32	9	11	8	7	10	45	12	10	12	9	11	54
5	1	3	3	13	2	2	4	3	4	15	4	6	3	5	4	22	5	3	3	4	5	20
7	8	6	8	36	6	5	4	6	9	30	7	8	8	8	7	38	10	8	11	11	10	50
8	7	7	7	35	7	7	7	8	5	34	6	9	8	10	10	43	8	9	12	10	10	49
7	7	7	7	34	6	6	6	7	7	32	5	8	10	9	6	38	8	9	9	9	10	45
4	4	5	4	21	5	4	4	5	6	24	7	6	9	7	8	37	7	8	7	8	7	37
2	4	5	4	20	3	5	6	4	5	23	5	5	4	5	4	23	12	6	6	3	4	31
7	3	7	3	24	4	6	6	7	2	25	8	8	8	7	6	37	5	9	8	5	9	36
6	7	5	6	31	5	8	7	5	4	29	4	7	8	8	6	33	10	9	6	6	7	38
5	7	7	5	29	5	5	5	6	4	25	7	6	7	6	6	32	9	9	7	9	8	42
4	147	154	146	740	134	158	144	153	152	741	171	189	191	181	194	926	223	214	210	215	211	1073
8	5.9	6.2	5.9	29.6	5.4	6.3	5.8	6.1	6.1	29.6	6.8	7.6	7.6	7.2	7.8	37.0	8.9	8.6	8.4	8.6	8.4	42.9

TABLE III - NUMBER OF PROBLEMS COMPLETED DURING E

Subject	Thirty-Minute Work																			
III A	5	5	6	4	2	22	3	6	4	1	3	17	2	0	4	2	6	14	2	4
III B	4	5	4	3	3	19	6	4	4	2	4	20	2	3	3	3	4	15	3	3
III C	6	6	6	5	5	28	6	4	6	6	7	29	5	6	4	5	8	28	6	8
III D	7	5	7	3	5	27	2	5	5	6	4	22	5	5	5	5	4	24	4	4
III E	7	9	9	8	8	41	6	7	5	5	6	29	5	10	9	9	10	43	7	9
III F	4	3	2	4	5	18	3	5	4	5	4	21	4	3	3	5	4	19	5	3
III G	5	5	9	5	5	29	4	6	5	5	6	26	8	3	9	8	5	33	8	10
III H	4	4	3	4	3	18	4	4	6	4	4	22	5	2	2	5	4	18	4	4
III I	4	5	4	6	4	23	4	5	3	4	5	21	3	1	3	4	4	15	4	5
III J	6	5	4	5	5	25	3	4	4	5	3	19	4	4	6	4	4	22	5	5
III K	4	3	3	5	7	22	4	5	4	4	5	22	2	2	4	5	4	17	5	5
III L	11	9	9	7	11	47	10	10	9	12	7	48	13	9	10	10	9	51	11	8
III M	4	6	7	5	5	27	5	4	5	5	6	25	6	6	6	5	5	28	8	9
III N	4	4	5	5	3	21	2	4	4	4	3	17	4	4	2	5	4	19	5	4
III O	5	2	6	5	6	24	4	7	4	3	6	24	1	5	5	4	4	19	3	4
III P	5	2	4	5	5	21	2	2	4	4	3	15	4	3	1	2	4	14	4	4
III Q	7	6	5	3	4	25	3	3	4	2	3	15	4	4	1	8	3	20	3	5
III R	4	4	5	6	3	22	3	5	4	5	5	22	3	6	5	5	5	24	4	5
III S	5	7	7	6	7	32	7	7	4	7	5	30	7	7	5	8	10	37	7	8
III T	3	4	3	3	4	17	3	5	2	5	2	17	1	5	4	3	5	18	5	6
III U	5	2	3	7	2	19	4	5	4	3	6	22	4	4	5	4	2	19	4	2
III V	6	9	8	9	8	40	6	2	6	7	5	26	3	4	7	6	8	28	6	7
III W	6	8	8	9	3	34	6	6	8	8	6	34	7	9	8	10	6	40	7	8
III X	4	3	2	1	5	15	4	4	5	4	4	21	7	5	4	6	6	28	5	3
III Y	5	7	9	7	7	35	7	8	6	9	5	35	6	7	9	9	8	39	7	12
Total	130	128	138	130	125	651	111	127	119	123	119	599	115	117	124	140	136	632	132	145
Av. per Minute	5.2	5.1	5.5	5.2	5.0	26.0	4.4	5.1	4.8	4.9	4.8	23.9	4.6	4.7	4.9	5.6	5.4	25.3	5.3	5.8

LETED DURING EACH MINUTE OF THREE WORK PERIODS FOR EACH SUBJECT OF CONDITION III

y-Minute Work Period																			Test Immediately after Rest				
14	2	4	4	4	1	15	4	4	5	8	6	27	7	4	5	4	8	28	6	5	5	8	6
15	3	3	3	4	5	18	6	4	3	4	3	20	5	3	5	4	4	21	6	7	7	7	3
28	6	8	5	6	4	29	6	5	5	7	6	29	6	4	7	7	5	29	8	9	8	7	7
24	4	4	3	6	7	24	6	5	6	6	5	28	6	7	7	9	7	36	10	6	7	7	8
43	7	9	8	6	11	41	9	9	9	9	11	47	11	11	12	11	11	56	8	14	13	12	12
19	5	3	3	5	3	19	3	3	6	7	4	23	4	7	4	5	7	27	6	6	7	6	6
33	8	10	7	7	8	40	8	2	8	8	9	35	6	6	11	10	7	40	9	10	9	13	8
18	4	4	2	5	4	19	5	6	5	4	4	24	6	5	5	5	3	24	5	6	8	9	6
15	4	5	4	6	5	24	5	5	4	2	5	21	4	3	4	4	3	18	7	5	5	4	5
22	5	5	5	5	4	24	7	6	5	6	6	30	5	7	3	5	6	26	5	5	6	5	6
17	5	5	5	6	3	24	5	4	7	5	6	27	4	3	4	4	6	21	4	8	7	6	6
51	11	8	11	11	11	52	12	12	13	11	11	59	12	12	11	12	12	59	16	13	15	14	14
28	8	9	5	6	4	32	6	6	5	6	8	31	8	7	7	8	7	37	8	7	9	8	8
19	5	4	4	1	3	17	2	5	5	3	6	21	3	5	4	4	3	19	5	4	5	3	5
19	3	4	4	4	6	21	8	5	5	5	4	27	5	7	6	3	4	25	6	5	6	5	6
14	4	4	4	5	5	22	5	7	5	6	4	27	4	3	6	7	6	26	7	7	7	10	9
20	3	5	0	6	4	18	4	3	5	5	2	19	5	5	5	3	5	23	4	4	4	7	4
24	4	5	5	7	6	27	6	5	6	7	5	29	5	5	8	4	4	26	7	6	8	7	6
37	7	8	7	5	5	32	7	9	8	7	9	40	8	9	9	7	10	43	9	9	10	12	11
18	5	6	6	4	2	23	5	6	7	4	6	28	7	3	6	4	5	25	6	8	9	7	7
19	4	2	1	4	5	16	4	6	3	7	3	23	7	5	5	7	5	29	6	7	9	8	6
28	6	7	8	7	4	32	7	5	2	7	9	30	7	8	5	7	9	36	7	8	7	8	10
40	7	8	8	6	9	38	9	10	11	13	9	52	8	9	9	8	8	42	12	11	12	10	10
28	5	3	4	5	7	24	5	7	5	6	4	27	5	6	4	3	3	21	5	8	11	5	10
39	7	12	9	8	10	46	11	4	10	10	11	46	7	11	8	10	9	45	12	13	12	12	10
632	132	145	125	139	136	677	155	143	153	163	156	770	155	155	160	155	157	782	184	193	206	200	191
25.3	5.3	5.8	5.0	5.5	5.4	27.1	6.2	5.7	6.1	6.5	6.2	30.8	6.2	6.2	6.4	6.2	6.3	31.3	7.4	7.7	8.2	8.0	7.6

RIODS FOR EACH SUBJECT OF CONDITION III

										Test Immediately after Rest						Test the Next Day					
8	6	27	7	4	5	4	8	28	6	5	5	8	6	30	6	6	8	7	11	38
4	3	20	5	3	5	4	4	21	6	7	7	7	3	30	4	5	7	8	7	31
7	6	29	6	4	7	7	5	29	8	9	8	7	7	39	10	6	9	4	8	37
6	5	28	6	7	7	9	7	36	10	6	7	7	8	38	7	7	9	11	8	42
9	11	47	11	11	12	11	11	56	8	14	13	12	12	59	9	13	13	11	14	60
7	4	23	4	7	4	5	7	27	6	8	7	6	8	35	4	7	9	7	8	35
8	9	35	6	6	11	10	7	40	9	10	9	13	8	49	11	9	10	11	8	49
4	4	24	6	5	5	5	3	24	5	6	8	9	6	34	6	6	8	7	8	35
2	5	21	4	3	4	4	3	18	7	5	5	4	5	26	6	6	7	5	8	32
6	6	30	5	7	3	5	6	26	5	5	6	5	6	27	5	4	5	7	7	28
5	6	27	4	3	4	4	6	21	4	8	7	6	6	31	2	8	7	5	9	31
11	11	59	12	12	11	12	12	59	16	13	15	14	14	72	18	14	16	14	11	73
6	8	31	8	7	7	8	7	37	8	7	9	8	8	40	9	7	9	9	9	43
3	6	21	3	5	4	4	3	19	5	4	5	3	5	22	5	5	5	4	5	24
5	4	27	5	7	6	3	4	25	6	5	6	5	6	28	6	5	8	7	8	34
6	4	27	4	3	6	7	6	26	7	7	7	10	9	40	10	9	9	10	10	48
5	2	19	5	5	5	3	5	23	4	4	4	7	4	23	6	7	4	4	6	27
7	5	29	5	5	8	4	4	26	7	6	8	7	6	34	8	5	9	6	8	36
7	9	40	8	9	9	7	10	43	9	9	10	12	11	51	10	11	12	12	11	56
4	6	28	7	3	6	4	5	25	6	8	9	7	7	37	9	8	7	11	10	45
7	3	23	7	5	5	7	5	29	6	7	9	8	6	36	6	8	7	8	6	35
7	9	30	7	8	5	7	9	36	7	8	7	8	10	40	10	11	7	10	8	46
13	9	52	8	9	9	8	8	42	12	11	12	10	10	55	12	12	13	10	10	57
6	4	27	5	6	4	3	3	21	5	8	11	5	10	39	8	8	8	4	7	35
10	11	46	7	11	8	10	9	45	12	13	12	12	10	59	13	12	12	10	11	58
163	156	770	155	155	160	155	157	782	184	193	206	200	191	974	200	199	219	201	216	1035
6.5	6.2	30.8	6.2	6.2	6.4	6.2	6.3	31.3	7.4	7.7	8.2	8.0	7.6	38.9	8.0	7.9	8.8	8.0	8.6	41.5

TABLE IV - NUMBER OF PROBLEMS COMPLETED DURING EACH

Subject	Thirty-Minute Work Per																				
IV A	3	4	5	3	4	19	2	3	3	5	3	16	4	5	3	3	4	19	4	5	4
IV B	3	2	3	5	4	17	5	3	4	4	3	19	3	3	6	4	4	20	7	4	2
IV C	6	7	6	6	7	32	7	7	2	8	6	30	7	5	6	9	8	35	7	8	7
IV D	6	10	6	7	9	38	6	9	7	8	6	36	8	6	8	8	7	37	6	8	6
IV E	5	3	6	5	5	24	4	2	3	4	6	19	4	2	5	5	6	22	3	2	4
IV F	3	3	6	3	7	22	3	5	6	6	4	24	2	1	8	5	6	22	3	7	5
IV G	4	4	2	4	4	18	2	3	6	4	5	20	4	2	4	3	2	15	3	5	5
IV H	4	3	6	2	4	19	5	4	5	4	6	24	3	6	5	7	6	27	5	3	5
IV I	5	5	7	6	6	29	5	5	7	3	7	27	6	7	8	8	8	37	7	1	9
IV J	4	3	3	6	3	19	5	5	4	4	5	21	3	4	5	5	4	21	5	6	5
IV K	8	11	7	8	8	42	7	9	8	6	8	38	9	8	9	9	10	45	9	8	9
IV L	5	8	6	7	7	33	5	6	3	9	5	28	6	7	5	8	7	33	7	7	8
IV M	5	7	8	7	6	35	9	5	8	6	5	33	8	7	10	10	6	41	9	6	7
IV N	3	5	5	4	5	22	3	6	3	5	4	21	4	6	6	5	6	27	4	4	6
IV O	6	6	5	4	6	27	5	6	5	5	6	27	5	6	4	7	5	27	5	7	7
IV P	3	4	1	3	3	14	3	2	2	4	4	15	3	1	2	1	4	11	3	2	3
IV Q	2	4	3	3	4	16	3	3	5	4	4	19	4	2	0	3	3	12	4	5	3
IV R	1	4	2	2	1	10	3	3	3	2	2	13	2	5	3	2	4	16	1	4	2
IV S	5	6	6	4	4	25	3	6	5	7	3	24	4	7	6	5	4	26	4	5	6
IV T	5	4	3	4	3	19	4	5	3	3	3	18	4	3	3	5	6	21	2	3	4
IV U	4	4	5	6	4	23	5	4	7	7	2	25	7	8	3	7	7	32	9	9	8
IV V	6	5	8	7	8	34	6	6	6	8	7	33	7	4	6	9	8	34	9	9	9
IV W	7	6	6	4	7	30	5	7	5	3	7	27	4	6	3	6	9	28	6	5	7
IV X	3	3	3	5	4	18	4	4	3	4	5	20	3	5	3	6	4	21	3	6	4
IV Y	1	5	6	4	6	22	3	5	5	7	4	24	2	5	4	3	6	20	2	1	2
Total	107	126	124	119	129	605	110	123	118	130	120	601	116	121	125	143	144	649	127	130	137
Av. per Minute	4.3	5.0	4.9	4.8	5.2	24.2	4.4	4.9	4.7	5.2	4.8	24.0	4.6	4.8	5.0	5.7	5.8	25.9	5.1	5.2	5.5

EACH MINUTE OF THREE WORK PERIODS FOR EACH SUBJECT OF CONDITION IV

rk Period																	Test Immediately after Rest						Te
5	4	4	1	18	4	6	5	4	6	25	6	4	4	6	4	24	5	2	6	7	6	26	4
4	2	2	3	18	3	5	3	5	5	21	5	5	6	6	7	29	6	4	7	6	9	32	6
8	7	8	7	37	6	6	10	8	9	39	9	8	8	8	10	45	9	8	11	10	10	46	11
8	6	8	8	36	8	7	7	9	12	43	10	10	6	7	7	40	8	9	11	11	13	52	12
2	4	4	6	19	7	6	6	5	5	29	5	5	5	5	4	24	3	5	8	8	7	31	6
7	5	8	8	31	7	5	7	3	4	26	5	4	5	8	8	30	9	7	10	7	9	42	8
5	5	3	5	21	2	4	7	8	7	28	6	6	5	5	4	26	7	7	9	9	9	41	9
3	5	6	5	24	6	6	6	7	6	51	4	5	6	6	6	27	7	6	8	9	7	37	7
1	9	8	5	30	5	8	10	11	10	44	8	11	10	7	11	47	11	8	9	8	13	49	13
6	5	5	6	27	7	5	1	5	5	23	7	3	5	6	7	28	7	9	7	5	4	32	7
8	9	11	7	44	9	11	9	12	8	49	12	12	8	10	10	52	12	12	11	10	13	58	12
7	8	7	5	34	4	8	10	9	5	36	9	10	11	8	8	46	9	13	13	10	12	57	10
6	7	8	10	40	10	9	7	9	9	44	10	10	9	6	8	43	12	11	9	13	10	55	12
4	6	5	6	25	7	6	7	6	5	31	6	5	6	6	6	29	8	10	9	8	7	42	10
7	7	7	6	32	7	8	4	7	6	32	7	7	4	5	8	31	7	8	9	9	9	42	9
2	3	4	3	15	0	3	3	1	2	9	3	3	3	3	5	17	6	8	6	5	6	31	5
5	3	4	4	20	2	1	4	4	4	15	3	2	3	4	3	15	5	4	6	6	4	25	2
4	2	2	4	13	4	2	3	5	5	19	3	3	5	4	7	22	5	6	6	5	3	25	4
5	6	7	6	28	5	6	7	8	5	31	6	7	6	4	10	33	9	7	10	8	9	43	12
3	4	3	3	15	3	6	6	4	4	23	4	5	6	6	6	27	6	7	6	7	7	33	8
9	8	8	9	43	9	8	10	9	9	45	10	10	10	12	12	54	11	10	11	12	14	58	11
9	9	8	8	43	10	7	11	5	9	42	9	7	10	9	8	43	13	12	15	12	10	62	16
5	7	7	8	33	5	7	6	6	5	29	9	7	7	6	10	39	9	10	9	9	10	47	10
6	4	6	4	23	4	4	9	6	5	28	6	6	6	4	5	27	7	6	5	7	8	33	7
1	2	3	3	11	5	4	6	6	7	28	4	5	5	6	2	22	6	6	8	6	6	32	7
30	137	146	140	680	139	148	164	162	157	770	166	160	159	157	176	818	197	195	219	207	215	1033	218
.2	5.5	5.8	5.6	27.2	5.6	5.9	6.5	6.5	6.3	30.8	6.6	6.4	6.4	6.3	7.1	32.7	7.9	7.8	8.8	8.3	8.6	41.3	8.8

[cut off] PERIODS FOR EACH SUBJECT OF CONDITION IV

												Test Immediately after Rest						Test the Next Day					
6	5	4	6	25	6	4	4	6	4	24	5	2	6	7	6	26	4	6	4	7	6	27
5	3	5	5	21	5	5	6	6	7	29	6	4	7	6	9	32	6	8	3	10	9	36
6	10	8	9	39	9	8	8	8	10	43	9	8	11	10	10	48	11	11	10	8	7	47
7	7	9	12	43	10	10	6	7	7	40	8	9	11	11	13	52	12	12	14	12	11	61
6	6	5	5	29	5	5	5	5	4	24	3	5	8	8	7	31	6	7	9	6	3	31
5	7	3	4	26	5	4	5	8	8	30	9	7	10	7	9	42	8	8	8	7	9	40
4	7	8	7	28	6	6	5	5	4	26	7	7	9	9	9	41	9	10	5	8	5	37
6	6	7	6	31	4	5	6	6	6	27	7	6	8	9	7	37	7	7	9	10	8	41
8	10	11	10	44	8	11	10	7	11	47	11	8	9	8	13	49	13	9	8	10	9	49
5	1	5	5	23	7	3	5	6	7	28	7	9	7	5	4	32	7	9	6	7	6	35
1	9	12	8	49	12	12	8	10	10	52	12	12	11	10	13	58	12	13	12	12	13	62
8	10	9	5	36	9	10	11	8	8	46	9	13	13	10	12	57	10	11	13	11	12	57
9	7	9	9	44	10	10	9	6	8	43	12	11	9	13	10	55	12	13	13	12	8	58
6	7	6	5	31	6	5	6	6	6	29	8	10	9	8	7	42	10	9	10	10	11	50
8	4	7	6	32	7	7	4	5	8	31	7	8	9	9	9	42	9	8	9	6	7	39
3	3	1	2	9	3	3	3	3	5	17	6	8	6	5	6	31	5	6	7	6	6	30
1	4	4	4	15	5	2	3	4	3	15	5	4	6	6	4	25	2	6	6	6	7	27
2	3	5	5	19	3	3	5	4	7	22	5	6	6	5	3	25	4	6	4	6	6	26
6	7	8	5	31	6	7	6	4	10	33	9	7	10	8	9	43	12	10	11	6	10	49
6	6	4	4	23	4	5	6	6	6	27	6	7	6	7	7	33	8	6	8	7	10	39
8	10	9	9	45	10	10	10	12	12	54	11	10	11	12	14	58	11	12	13	14	10	60
7	11	5	9	42	9	7	10	9	8	43	13	12	15	12	10	62	16	12	13	15	12	68
7	6	6	5	29	9	7	7	6	10	39	9	10	9	9	10	47	10	11	8	10	9	48
4	9	6	5	28	6	6	6	4	5	27	7	6	5	7	8	33	7	6	8	7	5	33
4	6	6	7	28	4	5	5	6	2	22	6	6	8	6	6	32	7	8	4	8	5	32
8	164	162	157	770	166	160	159	157	176	818	197	195	219	207	215	1033	218	224	215	221	204	1082
9	6.5	6.5	6.3	30.8	6.6	6.4	6.4	6.3	7.1	32.7	7.9	7.8	8.8	8.3	8.6	41.3	8.8	8.9	8.6	8.8	8.2	43.2

TABLE V - NUMBER OF PROBLEMS COMPLETED DURING EACH

Subject																		Thirty-Minute Work P	
V A	4	2	3	4	3	16	3	4	3	2	3	15	3	2	4	2	2	13	1	2
V B	6	6	7	5	3	27	5	5	6	5	2	23	6	4	5	5	5	25	4	4
V C	6	6	8	5	4	29	5	6	5	5	5	26	6	4	5	5	8	28	7	6
V D	6	9	7	8	8	38	8	6	6	7	8	35	8	9	9	8	7	41	7	8
V E	4	3	5	5	4	21	3	6	5	6	2	22	5	0	4	6	3	18	2	4
V F	3	3	4	3	6	19	3	3	5	4	6	21	5	3	4	5	5	22	5	2
V G	3	2	5	5	6	21	5	6	2	5	5	23	3	7	4	7	5	26	6	6
V H	3	3	4	5	4	19	2	3	3	3	1	12	4	3	2	4	4	17	2	5
V I	6	8	6	7	6	33	8	4	4	4	5	25	4	4	3	5	4	20	3	6
V J	6	8	8	8	8	38	8	6	9	10	9	42	11	9	9	8	9	46	9	10
V K	5	6	9	8	7	35	7	5	2	5	5	24	6	5	7	6	8	32	7	5
V L	8	7	7	5	4	31	7	5	6	8	7	33	4	7	7	9	7	34	6	7
V M	3	3	4	5	6	21	3	6	3	3	6	21	4	2	0	1	3	10	6	6
V N	4	7	7	6	8	32	3	5	3	5	9	25	4	5	2	5	4	20	4	10
V O	3	4	3	5	4	19	1	3	2	4	3	13	1	1	4	4	3	13	2	0
V P	3	4	3	4	5	19	3	3	5	5	4	20	3	5	2	5	4	19	4	4
V Q	5	3	5	5	6	24	4	4	6	4	3	21	5	5	6	4	5	25	5	5
V R	3	6	8	6	5	28	5	6	5	5	4	25	5	5	5	5	6	26	7	9
V S	4	3	4	3	5	19	5	4	6	6	4	25	3	4	7	6	4	24	7	4
V T	5	6	6	6	5	28	3	5	5	5	6	24	5	6	3	5	6	25	4	4
V U	5	2	5	6	5	23	2	5	7	6	2	22	7	5	5	5	4	26	3	7
V V	5	5	6	4	6	26	5	1	0	8	3	17	3	6	2	6	3	20	5	9
V W	4	4	3	6	6	23	3	3	4	2	3	15	4	5	1	6	5	21	4	5
V X	5	7	6	5	7	30	5	7	6	5	7	30	7	7	5	6	7	32	8	6
V Y	4	4	6	5	0	19	4	5	5	5	7	26	3	4	6	4	5	22	4	5
Total	113	121	139	134	131	638	110	116	113	127	119	585	119	117	111	132	126	605	122	139
Av. per Minute	4.5	4.8	5.6	5.4	5.2	25.5	4.4	4.6	4.5	5.1	4.8	23.4	4.8	4.6	4.4	5.3	5.0	24.2	4.8	5.6

DURING EACH MINUTE OF THREE WORK PERIODS FOR EACH SUBJECT OF CONDITION V

nute Work Period																		Test Immediately after Rest					
1	2	3	3	3	12	2	2	1	1	5	11	3	4	3	2	3	15	4	4	4	4	4	20
4	4	7	7	6	28	5	7	7	4	5	28	5	6	5	8	8	32	5	7	9	8	8	37
7	6	5	8	7	33	7	6	5	8	7	33	6	5	6	6	6	29	7	6	8	6	6	33
7	8	8	10	8	41	10	8	10	12	7	47	6	10	7	11	9	43	10	12	13	12	10	57
2	4	2	2	5	15	1	4	4	6	6	21	4	5	7	5	6	27	4	6	5	7	8	30
5	2	5	3	2	17	5	5	5	5	5	25	4	6	5	5	5	25	4	6	6	6	7	29
6	6	9	4	5	30	7	6	8	7	6	34	7	8	8	6	6	35	5	8	8	8	8	37
2	5	2	3	3	15	3	4	5	3	2	17	4	4	3	4	3	18	5	4	4	3	2	18
3	6	8	6	6	29	7	6	6	5	7	31	4	5	7	8	7	31	6	6	8	8	10	38
9	10	13	11	11	54	11	10	12	11	7	51	11	10	13	13	10	57	9	12	13	10	13	57
7	5	7	7	6	32	5	7	6	8	10	36	5	8	8	8	9	38	11	11	9	6	11	48
6	7	5	3	4	25	5	7	9	9	4	34	8	8	8	6	6	36	10	8	7	9	8	42
6	6	4	4	3	23	4	6	9	7	6	32	5	5	7	5	6	28	4	8	8	8	8	36
4	10	6	9	7	36	5	7	7	8	4	31	6	7	7	8	7	35	10	11	10	9	9	49
2	0	3	5	3	13	1	5	3	3	4	16	3	4	4	5	5	21	3	6	4	6	4	23
4	4	2	1	4	15	3	4	6	6	3	22	5	5	5	4	4	23	6	4	4	4	5	23
5	5	6	7	4	27	5	6	5	8	4	28	4	4	7	5	6	26	5	5	7	7	6	30
7	9	7	7	7	37	7	6	7	6	7	33	7	8	8	7	9	39	8	8	9	7	9	41
7	4	5	2	6	24	6	4	4	6	7	27	8	4	5	8	9	34	4	7	9	7	10	37
4	4	7	6	7	28	7	4	5	5	6	27	6	2	3	6	5	22	6	7	6	7	6	32
3	7	8	6	7	31	7	8	5	5	4	29	8	9	8	6	8	39	10	9	11	10	8	48
5	9	7	6	8	35	4	5	7	8	6	30	4	8	9	5	6	32	7	8	8	8	4	35
4	5	6	7	7	29	5	4	6	5	6	26	4	7	6	6	6	29	9	6	10	4	5	34
8	6	9	9	8	40	4	8	10	9	7	38	9	7	8	10	8	42	7	9	8	10	10	44
4	5	5	7	6	27	5	5	7	7	5	29	5	5	8	4	5	27	5	7	8	7	7	34
122	139	149	143	143	696	131	144	159	162	140	736	141	154	165	161	162	783	164	185	196	181	186	912
4.8	5.6	5.9	5.7	5.7	27.8	5.2	5.8	6.4	6.5	5.6	29.4	5.6	6.2	6.6	6.4	6.5	31.3	6.6	7.4	7.8	7.2	7.4	36.5

DS FOR EACH SUBJECT OF CONDITION V

									Test Immediately after Rest						Test the Next Day					
1	5	11	3	4	3	2	3	15	4	4	4	4	4	20	5	4	4	4	5	22
4	5	28	5	6	5	8	8	32	5	7	9	8	8	37	10	9	9	10	10	48
8	7	33	6	5	6	6	6	29	7	6	8	6	6	33	8	7	8	8	9	40
12	7	47	6	10	7	11	9	43	10	12	13	12	10	57	16	11	12	8	15	62
6	6	21	4	5	7	5	6	27	4	6	5	7	8	30	7	7	7	8	6	35
5	5	25	4	6	5	5	5	25	4	6	6	6	7	29	6	8	7	7	7	35
7	6	34	7	8	8	6	6	35	5	8	8	8	8	37	10	8	8	9	9	44
3	2	17	4	4	3	4	3	18	5	4	4	3	2	18	4	4	4	5	4	21
5	7	31	4	5	7	8	7	51	6	6	8	8	10	38	11	9	8	8	6	42
11	7	51	11	10	13	13	10	57	9	12	13	10	13	57	10	12	14	11	14	61
8	10	36	5	8	8	8	9	38	11	11	9	6	11	48	10	11	10	11	12	54
9	4	34	8	8	8	6	6	36	10	8	7	9	8	42	10	9	10	9	5	43
7	6	32	5	5	7	5	6	28	4	8	8	8	8	36	7	7	7	9	7	37
8	4	31	6	7	7	8	7	35	10	11	10	9	9	49	14	12	11	13	10	60
3	4	16	3	4	4	5	5	21	3	6	4	6	4	23	6	4	6	8	7	31
6	3	22	5	5	5	4	4	23	6	4	4	4	5	23	4	5	4	4	6	23
8	4	28	4	4	7	5	6	26	5	5	7	7	6	30	7	7	6	5	6	31
6	7	33	7	8	8	7	9	39	8	8	9	7	9	41	7	10	11	10	12	50
6	7	27	8	4	5	8	9	34	4	7	9	7	10	37	11	9	9	11	11	51
5	6	27	6	2	3	6	5	22	6	7	6	7	6	32	6	5	7	7	6	31
5	4	29	8	9	8	6	8	39	10	9	11	10	8	48	10	7	11	9	10	47
8	6	30	4	8	9	5	6	32	7	8	8	8	4	35	7	7	6	6	8	34
5	6	26	4	7	6	6	6	29	9	6	10	4	5	34	6	10	9	7	7	39
9	7	38	9	7	8	10	8	42	7	9	8	10	10	44	10	12	8	7	9	46
7	5	29	5	5	8	4	5	27	5	7	8	7	7	34	7	9	7	6	8	37
162	140	736	141	154	165	161	162	783	164	185	196	181	186	912	209	203	203	200	209	1024
6.5	5.6	29.4	5.6	6.2	6.6	6.4	6.5	31.3	6.6	7.4	7.8	7.2	7.4	36.5	8.3	8.1	8.1	8.0	8.3	40.9

TABLE VI - NUMBER OF PROBLEMS COMPLETED DURING EAC

Subject	Thirty-Minute Work P																				
VI A	8	5	6	3	7	29	5	5	5	6	7	28	5	4	5	4	5	23	7	8	5
VI B	2	3	5	3	5	18	4	3	4	5	5	21	3	3	4	6	4	20	3	3	4
VI C	6	6	9	7	6	34	5	6	6	6	4	27	5	5	6	7	5	28	7	8	6
VI D	4	5	5	5	2	21	3	2	4	1	4	14	3	4	5	0	7	19	3	4	2
VI E	7	5	4	4	6	26	4	5	3	5	3	20	4	5	4	6	3	22	3	5	4
VI F	3	2	2	3	4	14	5	3	3	0	5	16	2	4	6	5	2	19	5	6	7
VI G	4	3	4	7	4	22	3	5	9	7	5	29	5	6	5	7	4	27	6	7	8
VI H	3	2	1	5	2	13	3	6	3	6	4	22	1	1	4	5	3	14	6	4	6
VI I	6	5	7	7	3	28	7	7	4	6	5	29	6	5	7	5	6	29	9	7	6
VI J	6	2	4	6	5	23	6	5	5	5	2	23	5	4	5	4	3	21	6	2	5
VI K	4	5	5	6	6	26	5	4	5	5	7	26	5	6	6	4	6	27	8	7	6
VI L	4	5	5	5	4	23	5	4	3	3	4	19	3	3	5	3	4	18	6	4	5
VI M	7	8	6	5	4	30	5	5	6	4	7	25	4	6	5	6	6	27	9	7	8
VI N	4	5	6	4	7	26	4	1	4	5	3	17	4	5	5	4	3	21	5	4	6
VI O	3	0	1	5	4	13	5	4	3	4	4	20	4	4	6	6	4	24	7	4	6
VI P	5	2	4	3	5	19	3	4	2	4	4	17	6	2	4	2	4	18	5	3	3
VI Q	4	4	5	3	3	19	5	2	4	2	3	16	2	3	5	5	4	19	5	3	2
VI R	5	7	7	6	5	30	4	1	4	3	5	17	6	6	5	4	4	25	5	5	7
VI S	5	6	5	6	6	28	3	4	6	6	4	23	7	5	5	6	4	27	5	7	7
VI T	10	15	12	11	16	64	7	13	13	11	11	55	12	15	15	15	12	69	16	17	13
VI U	5	2	5	6	1	19	1	2	3	4	3	13	1	0	3	3	5	12	3	5	4
VI V	0	5	4	4	6	19	3	2	4	4	3	16	6	5	2	4	6	23	5	5	2
VI W	5	4	6	8	4	27	7	4	8	1	5	25	7	6	5	4	4	26	7	8	8
VI X	6	6	7	6	5	30	6	7	6	8	5	32	5	8	8	8	7	36	6	7	7
VI Y	8	10	7	8	7	40	6	7	7	7	6	33	7	11	8	7	9	42	10	8	12
Total	124	122	132	136	127	641	112	111	124	118	118	583	118	126	138	130	124	636	157	148	149
Av. per Minute	4.9	4.9	5.3	5.4	5.1	25.6	4.5	4.4	4.9	4.7	4.7	23.3	4.7	5.0	5.5	5.2	4.9	25.4	6.3	5.9	6.0

URING EACH MINUTE OF THREE WORK PERIODS FOR EACH SUBJECT OF CONDITION VI

te Work Period																		Test Immediately after Rest						
7	8	5	5	6	31	4	4	6	5	6	25	7	8	7	4	7	33	6	8	8	7	7	36	
3	3	4	5	2	17	4	3	5	5	6	23	2	5	4	5	5	21	5	7	3	3	4	22	
7	8	6	6	7	34	8	8	5	10	8	39	5	7	8	6	7	33	10	9	9	8	5	41	
3	4	2	3	3	15	4	3	5	5	5	22	5	6	4	7	6	28	5	7	7	8	7	34	
3	5	4	6	6	24	5	4	2	5	7	23	7	5	4	3	6	25	8	8	4	6	6	32	
5	6	7	2	1	21	2	5	3	8	6	24	4	6	4	6	4	24	6	5	3	6	5	25	1
6	7	8	8	5	34	7	8	4	5	8	32	10	7	6	6	1	30	5	7	8	5	8	33	1
6	4	6	4	3	23	6	6	8	7	7	34	6	9	6	6	8	35	9	7	10	9	10	45	1
9	7	6	7	8	37	6	6	6	8	9	35	7	8	6	5	4	30	7	6	6	7	6	32	1
6	2	5	6	6	25	7	7	6	7	6	35	6	5	3	8	8	30	5	8	8	7	8	36	
8	7	6	6	7	34	5	7	5	9	6	32	7	7	8	8	9	39	9	6	10	9	5	39	
6	4	5	7	6	28	7	6	5	8	5	31	5	5	3	6	5	24	9	9	8	7	9	42	
9	7	8	7	6	37	6	5	4	7	10	32	8	7	6	7	11	39	8	8	8	9	7	40	1
5	4	6	7	5	27	6	4	5	8	8	31	5	6	7	6	7	31	6	6	7	7	8	34	
7	4	6	6	5	28	5	4	5	7	6	27	5	8	3	1	7	24	9	10	9	10	8	46	
5	3	3	3	3	17	3	2	3	3	4	15	4	5	4	5	3	21	3	5	5	4	4	21	
5	3	2	3	1	14	4	4	1	5	5	19	6	3	4	3	5	21	6	5	7	6	6	30	
5	5	7	7	8	32	3	0	5	4	4	16	6	7	7	7	6	33	11	8	7	7	9	42	1
5	7	7	7	4	30	6	8	6	8	6	34	7	6	7	5	6	31	6	5	6	7	10	34	
6	17	13	12	13	71	14	13	11	13	16	67	14	14	13	15	12	68	13	18	14	16	11	72	1
3	5	4	5	3	20	3	0	6	1	3	13	5	4	4	1	6	20	6	5	4	6	5	26	
5	5	2	3	3	18	8	8	4	6	6	32	5	7	7	3	4	26	7	8	7	8	7	37	1
7	8	8	7	8	38	7	4	7	6	5	29	8	8	5	8	6	35	7	7	8	6	8	36	1
6	7	7	8	6	34	8	7	9	9	8	41	7	6	8	7	8	36	7	9	10	6	9	41	1
0	8	12	10	9	49	7	8	10	7	9	41	9	8	11	9	11	48	16	11	11	12	12	62	1
7	148	149	150	134	738	145	134	136	166	169	750	160	167	149	147	162	785	189	192	187	186	184	938	23
3	5.9	6.0	6.0	5.4	29.5	5.8	5.4	5.4	6.6	6.8	30.0	6.4	6.7	6.0	5.9	6.5	31.4	7.6	7.7	7.5	7.4	7.4	37.5	9.

PERIODS FOR EACH SUBJECT OF CONDITION VI

										Test Immediately after Rest						Test the Next Day					
6	5	6	25	7	8	7	4	7	33	6	8	8	7	7	36	8	9	10	8	8	43
5	5	6	23	2	5	4	5	5	21	5	7	3	3	4	22	5	5	8	5	4	27
5	10	8	39	5	7	8	6	7	33	10	9	9	8	5	41	9	10	9	7	12	47
5	5	5	22	5	6	4	7	6	28	5	7	7	8	7	34	8	7	8	9	10	42
2	5	7	23	7	5	4	3	6	25	8	8	4	6	6	32	8	7	5	8	5	33
3	8	6	24	4	6	4	6.	4	24	6	5	3	6	5	25	11	8	7	10	14	50
4	5	8	32	10	7	6	6	1	30	5	7	8	5	8	33	10	9	5	8	8	40
8	7	7	34	6	9	6	6	8	35	9	7	10	9	10	45	11	10	11	12	11	55
6	8	9	35	7	8	6	5	4	30	7	6	6	7	6	32	10	11	11	11	11	54
6	7	6	35	6	5	3	8	8	30	5	8	8	7	8	36	9	8	7	10	9	43
5	9	6	32	7	7	8	8	9	39	9	6	10	9	5	39	8	9	8	8	8	41
5	8	5	31	5	5	3	6	5	24	9	9	8	7	9	42	7	8	8	10	8	41
4	7	10	32	8	7	6	7	11	39	8	8	8	9	7	40	12	14	9	13	10	58
5	8	8	31	5	6	7	6	7	31	6	6	7	7	8	34	8	8	7	8	8	39
5	7	6	27	5	8	3	1	7	24	9	10	9	10	8	46	8	12	9	12	12	53
3	3	4	15	4	5	4	5	3	21	3	5	5	4	4	21	5	7	6	5	5	28
1	5	5	19	6	3	4	3	5	21	6	5	7	6	6	30	8	5	7	7	6	33
5	4	4	16	6	7	7	7	6	33	11	8	7	7	9	42	10	10	10	8	8	46
6	8	6	34	7	6	7	5	6	31	6	5	6	7	10	34	7	7	9	7	7	37
11	13	16	67	14	14	13	15	12	68	13	18	14	16	11	72	15	17	15	16	17	80
6	1	3	13	5	4	4	1	6	20	6	5	4	6	5	26	9	5	8	6	6	34
4	6	6	32	5	7	7	3	4	26	7	8	7	8	7	37	10	10	10	8	10	48
7	6	5	29	8	8	5	8	6	35	7	7	8	6	8	36	10	9	9	6	9	43
9	9	8	41	7	6	8	7	8	36	7	9	10	6	9	41	10	13	11	12	12	58
10	7	9	41	9	8	11	9	11	48	16	11	11	12	12	62	14	13	12	11	12	62
136	166	169	750	160	167	149	147	162	785	189	192	187	186	184	938	230	231	219	225	230	1135
5.4	6.6	6.8	30.0	6.4	6.7	6.0	5.9	6.5	31.4	7.6	7.7	7.5	7.4	7.4	37.5	9.2	9.2	8.8	9.0	9.2	45.4

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TABLE VIII

RECOVERY RATIOS IN TERMS OF PROBLEMS WORKED CORRECTLY FOR EACH SUBJECT FOR CONDITION I

	I	II	III	IV	V	VI
Subject	Last 5 Min. of Initial Work Period	Test Immediately after Rest	Test Next Day	Change Bet. I & II	Change Bet. I & III	Ratio Bet. IV & V
I A	27	35	41	8	14	57.1
I B	37	45	53	8	16	50.0
I C	43	52	59	9	16	56.3
I D	12	23	30	11	18	61.1
I E	37	38	47	1	10	10.0
I F	27	35	43	8	16	50.0
I G	39	58	60	19	21	90.5
I H	38	41	43	3	5	60.0
I I	32	33	40	1	8	12.5
I J	23	29	38	6	15	40.0
I K	37	46	57	9	20	45.0
I L	19	19	22	0	3	00.0
I M	28	27	34	-1	6	-16.7
I N	27	30	47	3	20	15.0
I O	20	27	29	7	9	77.9
I P	22	28	32	6	10	60.0
I Q	24	23	31	-1	7	-14.3
I R	21	21	30	0	9	00.0
I S	24	28	40	4	16	25.0
I T	28	37	41	9	13	69.3
I U	23	30	36	7	13	53/8
I V	34	39	46	5	12	41.6
I W	37	41	47	4	10	40.0
I X	35	35	45	0	10	00.0
I Y	30	37	42	7	12	58.4
Total	724	857	1033	133	309	942.5
Average	29.0	34.3	41.7	5.3	12.3	37.7

TABLE IX

RECOVERY RATIOS IN TERMS OF PROBLEMS WORKED CORRECTLY FOR EACH SUBJECT FOR CONDITION II

	I	II	III	IV	V	VI
Subject	Last 5 Min. of Initial Work Period	Test Immediately after Rest	Test Next Day	Change Bet. I & II	Change Bet. I & III	Ratio Bet. IV & V
II A	26	38	52	12	26	46.0
II B	20	30	44	10	24	41.7
II C	22	23	27	1	5	20.0
II D	36	41	54	5	18	27.8
II E	51	57	61	6	10	60.0
II F	32	34	46	2	14	14.3
II G	14	23	22	9	8	112.5
II H	12	19	22	7	10	70.0
II I	25	29	37	4	12	33.3
II J	23	26	30	3	7	42.9
II K	30	30	41	0	11	00.0
II L	45	56	52	11	7	157.0
II M	44	55	59	11	15	73.3
II N	42	58	53	16	21	76.2
II O	23	30	28	7	5	140.0
II P	30	44	53	14	23	60.8
II Q	14	19	17	5	3	167.0
II R	26	35	46	9	20	45.0
II S	32	42	46	10	14	71.5
II T	27	35	43	8	16	50.0
II U	20	37	36	17	16	106.0
II V	23	23	31	2	8	25.0
II W	25	37	33	10	8	125.0
II X	27	31	37	4	10	40.0
II Y	22	27	41	5	19	26.3
Total	691	879	1021	188	330	1631.60
Average	27.6	35.2	40.8	7.5	13.2	65.25

TABLE X

RECOVERY RATIOS IN TERMS OF PROBLEMS WORKED CORRECTLY FOR EACH SUBJECT FOR CONDITION III

	I	II	III	IV	V	VI
Subject	Last 5 Min. of Initial Work Period	Test Immediately after Rest	Test Next Day	Change Bet. I & XI	Change Bet. I & III	Ratio Bet. IV & V
III A	28	29	38	1	10	10.0
III B	16	25	26	9	10	90.0
III C	25	37	34	12	9	133.3
III D	34	36	40	2	6	33.3
III E	53	59	57	6	4	150.0
III F	26	33	32	7	6	116.8
III G	38	47	46	9	8	112.5
III H	19	31	33	12	14	85.7
III I	16	23	31	7	15	46.6
III J	21	25	27	4	6	66.7
III K	20	31	31	11	11	100.0
III L	56	67	64	11	8	137.5
III M	37	38	43	1	6	16.7
III N	19	22	24	3	5	60.0
III O	23	25	32	2	9	22.2
III P	26	36	47	10	21	47.6
III Q	23	23	27	0	4	00.0
III R	24	31	28	7	4	175.0
III S	40	50	54	10	14	71.5
III T	25	36	40	11	15	73.3
III U	26	31	33	5	7	71.4
III V	36	40	45	4	9	44.4
III W	41	55	53	14	12	116.5
III X	21	36	35	15	14	107.1
III Y	41	55	56	14	15	93.4
Total	734	921	976	187	242	1981.56
Average	29.4	36.8	39.0	7.5	9.7	79.26

TABLE XI

RECOVERY RATIOS IN TERMS OF PROBLEMS WORKED CORRECTLY FOR EACH SUBJECT FOR CONDITION IV

	I	II	III	IV	V	VI
Subject	Last 5 Min. of Initial Work Period	Test Immediately after Rest	Test Next D Day	Change Bet. I & II	Change Bet. I & III	Ratio Bet. IV & V
IV A	18	25	25	7	7	100.0
IV B	25	31	33	6	8	75.0
IV C	43	47	47	4	4	100.0
IV D	33	46	51	13	18	72.3
IV E	23	30	29	7	6	116.7
IV F	28	41	38	13	10	130.0
IV G	25	40	37	15	12	125.0
IV H	26	37	40	11	14	78.6
IV I	44	46	49	2	5	40.0
IV J	26	31	34	5	8	62.5
IV K	52	55	59	3	7	42.9
IV L	46	57	54	11	8	137.5
IV M	41	53	55	12	14	85.5
IV N	28	43	46	15	18	83.4
IV O	28	40	38	12	10	120.0
IV P	17	30	29	13	12	108.2
IV Q	13	24	27	11	14	78.5
IV R	21	23	25	2	4	50.0
IV S	27	37	41	10	14	71.4
IV T	26	33	37	7	11	63.6
IV U	51	56	59	5	8	62.5
IV V	43	60	64	17	21	81.0
IV W	39	45	46	6	7	85.9
IV X	25	31	32	6	7	85.9
IV Y	22	31	31	9	9	100.0
Total	770	992	1026	222	256	2157.40
Average	30.8	39.6	40.9	8.9	10.2	86.30

TABLE XII

RECOVERY RATIOS IN TERMS OF PROBLEMS WORKED CORRECTLY FOR EACH SUBJECT FOR CONDITION V

	I	II	III	IV	V	VI
Subject	Last 5 Min. of Initial Work Period	Test Immediately after Rest	Test Next Day	Change Bet. I & II	Change Bet. I & III	Ratio Bet. IV & V
V A	12	17	21	5	9	55.6
V B	28	36	45	8	17	47.1
V C	25	28	35	3	10	30.0
V D	43	55	53	12	10	120.0
V E	27	29	31	2	4	50.0
V F	24	29	34	5	10	50.0
V G	35	37	44	2	9	22.2
V H	18	19	20	1	2	50.0
V I	28	37	37	9	9	100.0
V J	54	55	56	1	2	50.0
V K	36	46	53	10	17	61.2
V L	32	38	42	6	10	60.0
V M	28	34	36	6	8	75.0
V N	35	49	56	14	21	67.6
V O	20	23	30	3	10	30.0
V P	19	19	18	0	- 1	00.0
V Q	24	30	28	6	4	150.0
V R	37	36	48	- 1	11	- 91.0
V S	33	34	49	1	16	6.3
V T	19	27	29	8	10	80.0
V U	39	47	43	8	4	200.0
V V	31	33	34	2	3	66.7
V W	28	32	35	4	7	57.2
V X	42	43	46	1	4	25.0
V Y	25	26	34	1	9	11.1
Total	742	859	957	117	215	137.40
Average	29.7	34.4	38.3	4.7	8.6	54.9

TABLE XIII

RECOVERY RATIOS IN TERMS OF PROBLEMS WORKED CORRECTLY FOR EACH SUBJECT FOR CONDITION VI

	I	II	III	IV	V	VI
Subject	Last 5 Min. of Initial Work Period	Test Immediately after Rest	Test Next Day	Change Bet. I & II	Change Bet. I & III	Ratio Bet. IV & V
VI A	28	34	38	6	10	60.0
VI B	20	19	25	- 1	5	-20.0
VI C	28	38	46	10	18	55.5
VI D	27	33	42	6	15	40.0
VI E	19	26	26	7	7	100.0
VI F	22	23	49	1	27	3.7
VI G	29	32	38	3	9	33.33
VI H	35	42	54	7	19	36.80
VI I	29	29	54	0	25	0.00
VI J	30	36	39	6	9	66.7
VI K	39	38	36	- 1	- 3	33.33
VI L	24	41	39	17	15	113.2
VI M	36	36	52	0	16	0.00
VI N	29	28	32	- 1	3	-33.33
VI O	24	43	52	19	28	67.80
VI P	17	20	24	3	7	42.8
VI Q	19	30	30	11	11	100.0
VI R	33	41	41	8	8	100.0
VI S	27	30	31	3	4	75.0
VI T	63	65	80	2	17	11.8
VI U	19	24	33	5	14	35.8
VI V	26	34	44	8	18	44.5
VI W	35	36	43	1	8	12.5
VI X	36	39	57	3	21	14.3
VI Y	42	55	53	13	11	118.0
Total	736	872	1058	136	322	1111.73
Average	29.4	34.9	42.3	5.4	12.9	44.47

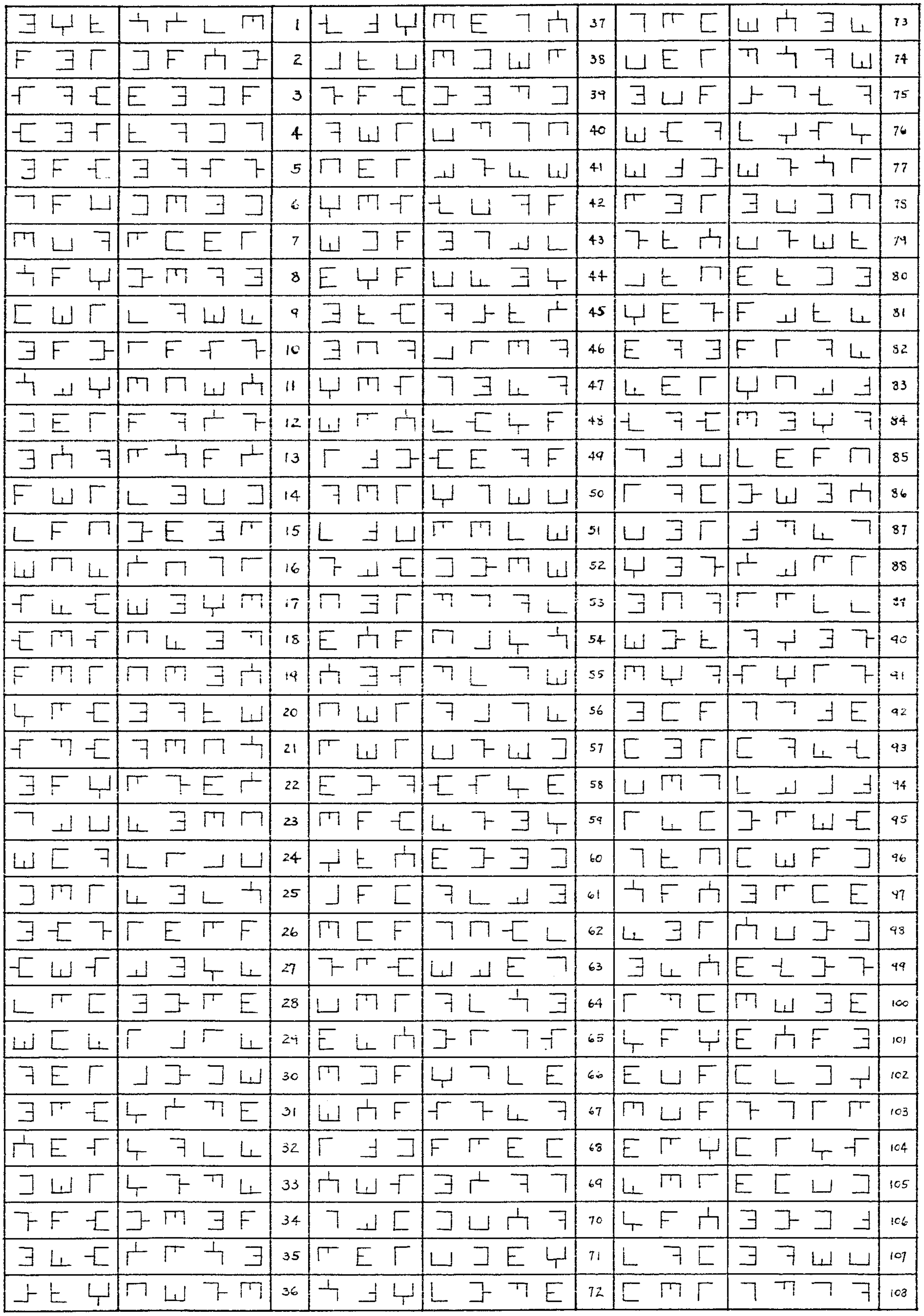
TABLE VII

COMPARISON OF AVERAGES, STANDARD DEVIATIONS, STANDARD ERRORS, AND CRITICAL RATIOS FOR TOTAL NUMBER OF PROBLEMS WORKED CORRECTLY FOR SIX DIFFERENT GROUPS

Conditions	Averages			Standard Deviation			Standard Errors			σ/D	C R's	σ/D	C R's
	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_2-M_1	M_2 M_1	M_3-M_1	M_3 M_1
I	29.0	34.3	41.7	7.54	10.98	9.76	1.51	1.96	1.95	1.41	3.8	.91	13.9
II	27.6	35.2	40.8	9.65	11.53	12.72	1.93	2.31	2.54	.98	7.8	1.46	9.0
III	29.4	36.8	39.0	10.65	12.47	10.82	2.13	2.49	2.16	1.09	6.8	.86	11.2
IV	30.8	39.6	40.9	10.91	10.71	11.09	2.18	2.14	2.21	.93	9.5	.93	10.9
V	29.7	34.4	38.3	9.11	10.37	10.73	1.82	2.08	2.33	.78	6.0	1.14	7.6
VI	29.4	34.9	42.3	9.49	10.25	12.24	1.90	2.05	2.45	1.35	4.1	1.51	8.6

M_1 = last 5 minutes of Initial Work Period
M_2 = 5 minutes of work Immediately after Rest
M_3 - 5 minutes of Work next Day

SHEET 1


1
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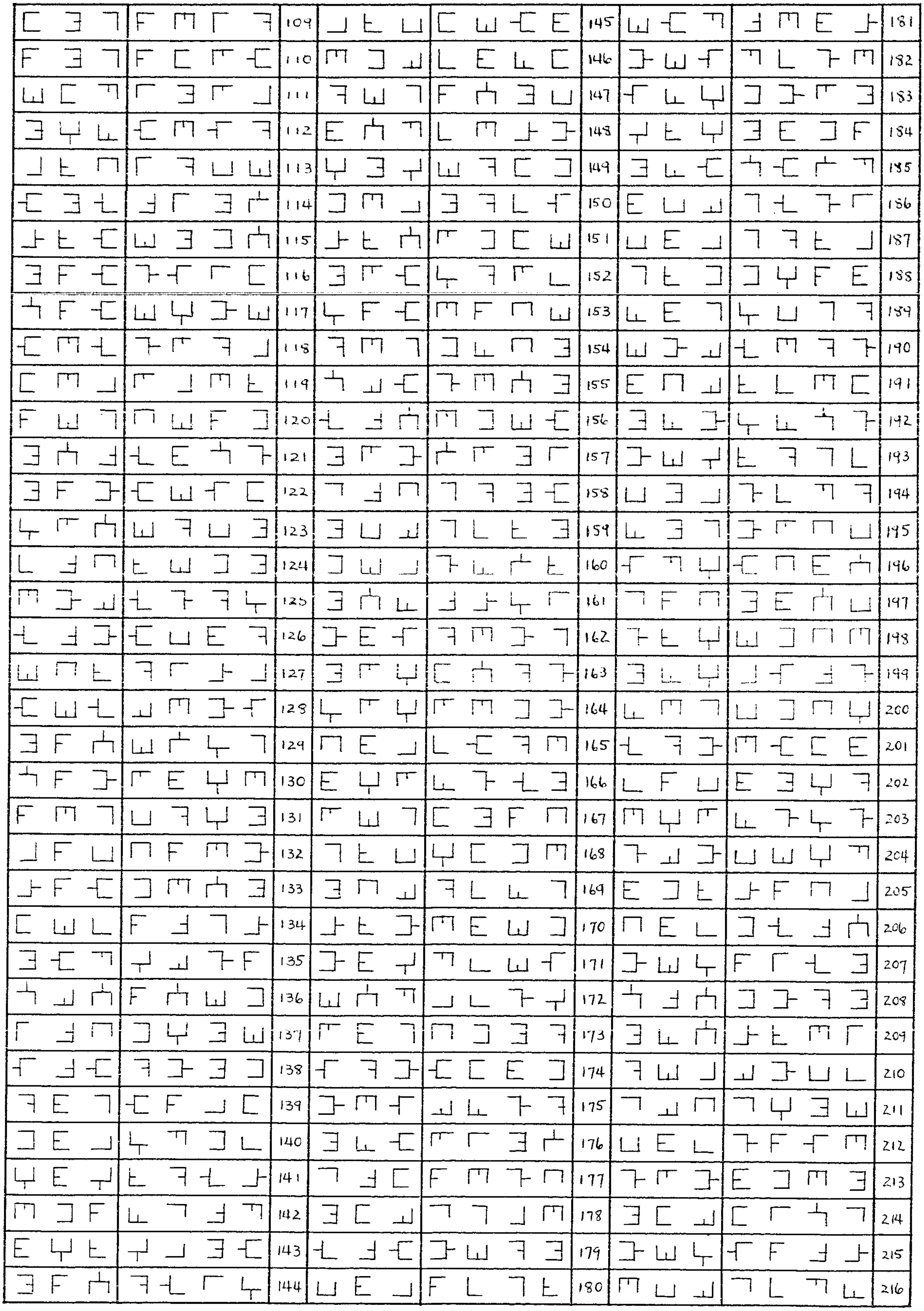
107
108

SHEET 2



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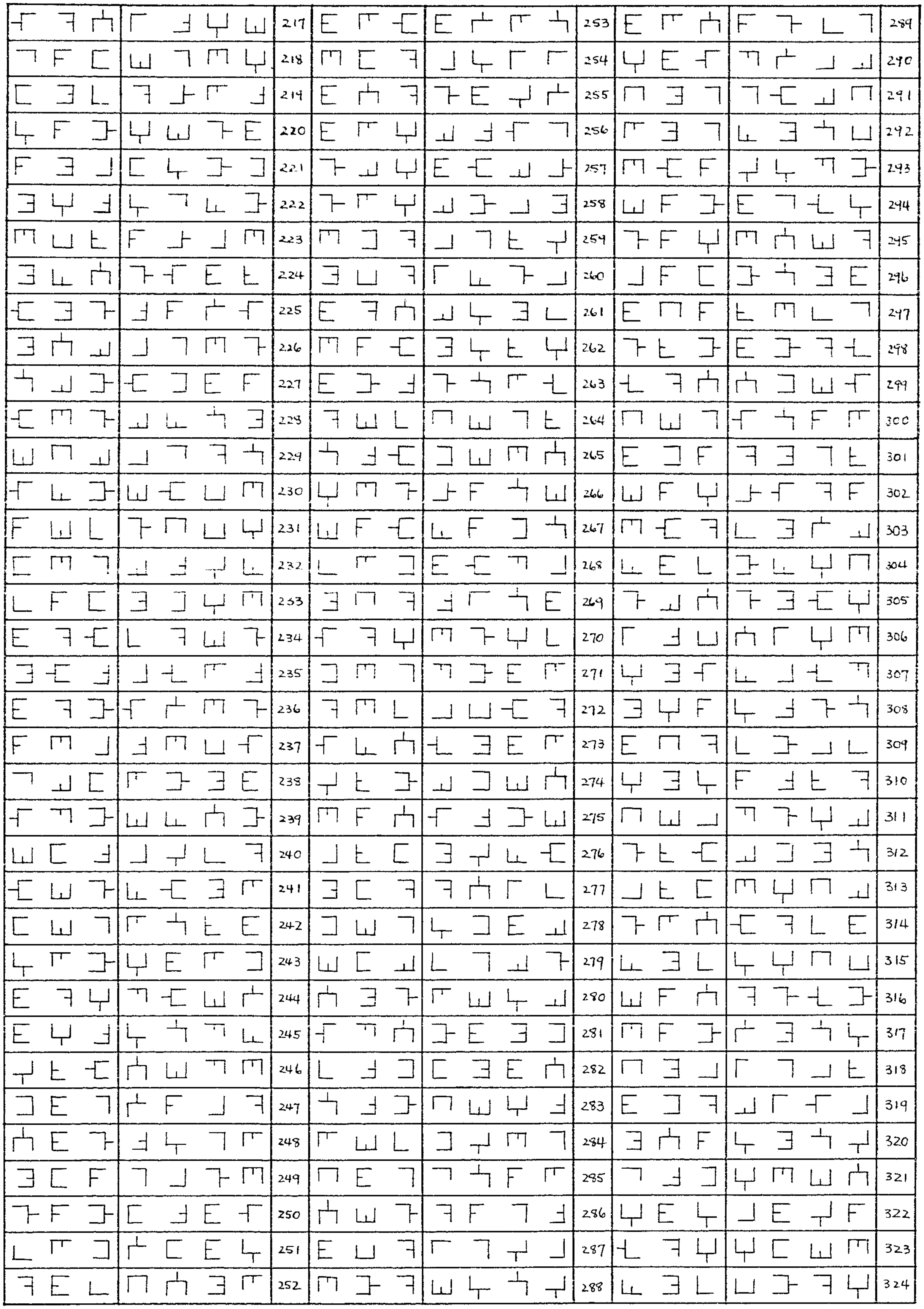
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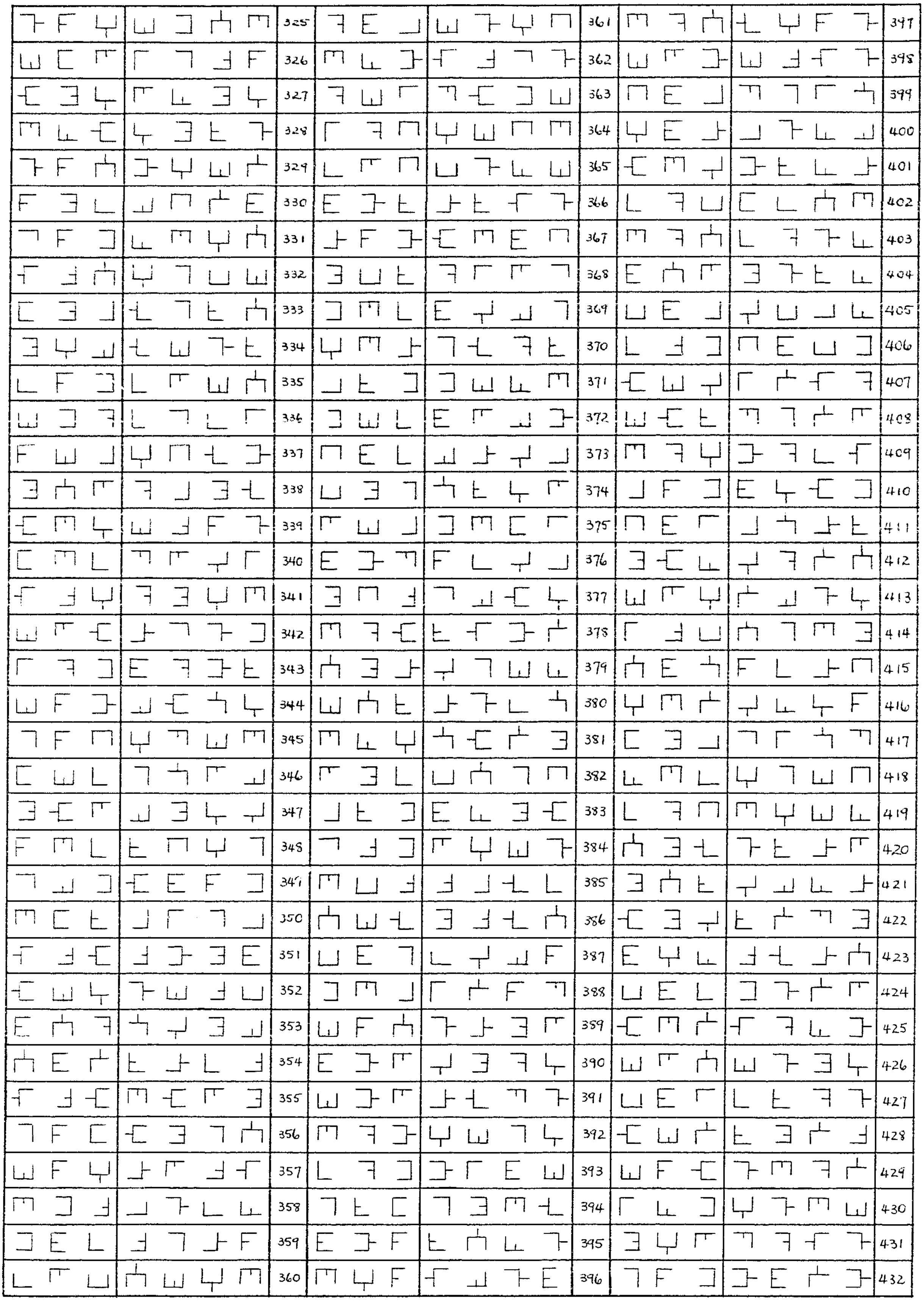
321
322
323
324

SHEET 4


325 361 397
326 362 398
327 363 399
328 364 400
329 365 401
330 366 402
331 367 403
332 368 404
333 369 405
334 370 406
335 371 407
336 372 408
337 373 409
338 374 410
339 375 411
340 376 412
341 377 413
342 378 414
343 379 415
344 380 416
345 381 417
346 382 418
347 383 419
348 384 420
349 385 421
350 386 422
351 387 423
352 388 424
353 389 425
354 390 426
355 391 427
356 392 428
357 393 429
358 394 430
359 395 431
360 396 432

INSTRUCTIONS TO THE SUBJECT

Our task consists of a group of analogies (see sample attached). You will notice the first character in each problem is to the second in some manner as the third is to one of four others in the same manner.

This is your first problem . What changes have been made in the first character to get the second? It has been rotated 90 degrees clockwise in the plane of the paper and the center bar has been moved outside. Now, if you rotate the third character 90 degrees clockwise and move the center bar outside which of the following four characters will you have made: ? The first is correct, that is to say, is to as is to .

In the second problem , in order to get the second character, the first character has been rotated 180 degrees in the plane of the paper, and an end bar has been added. If you make the same two changes in the third character, which of the four responses will be correct? The first is right.

In the third problem the second character is obtained by rotating the first character about its long bar and moving the center bar inside. Which will be the correct response , if you make the same two changes in the third character? The third is right.

On this board there are more problems of the foregoing type. With the stylus punch the correct answer for each problem. Work from the top to the bottom of each of the three vertical columns of problems.

Work as fast as you can consistent with accuracy. The efficiency of your work will be determined in terms of speed and accuracy.

YOU ARE TO WORK UNTIL I TELL YOU TO STOP.

CARD NO. 1

I feel more like working on this task than on any I have ever attempted

I feel worse than I ever have at the end of any task

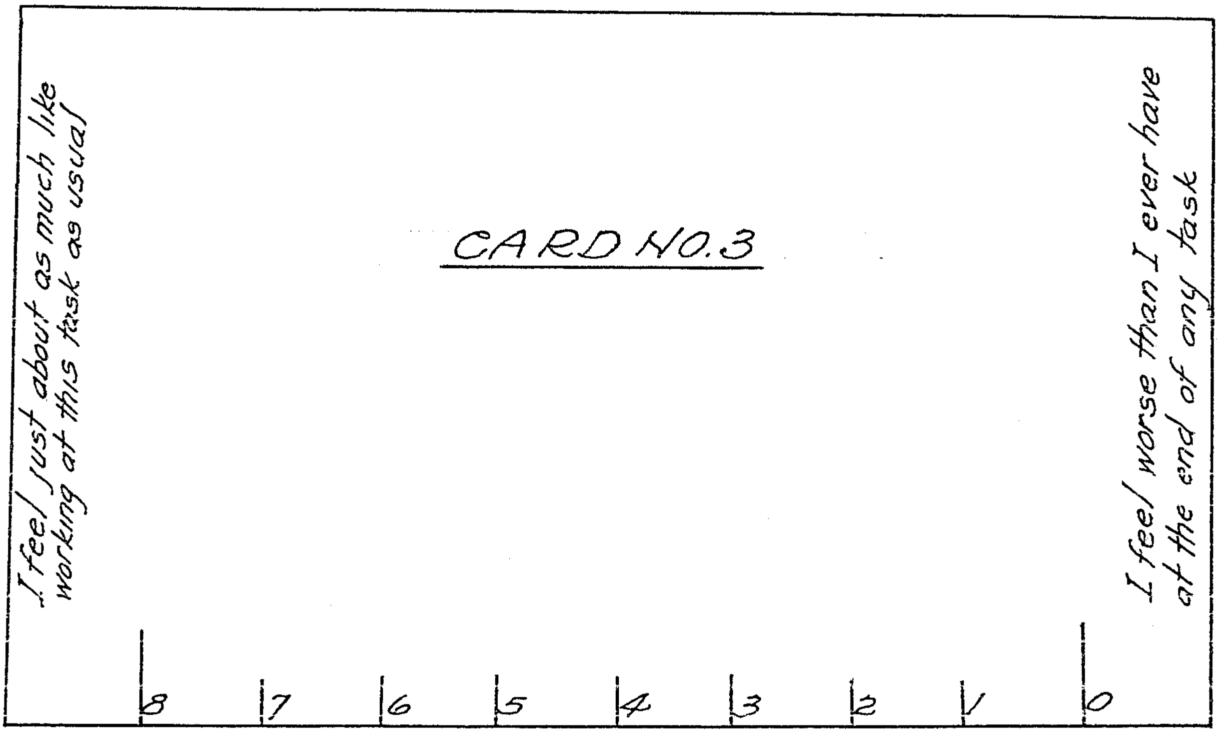
10	9	8	7	6	5	4	3	2	1	0

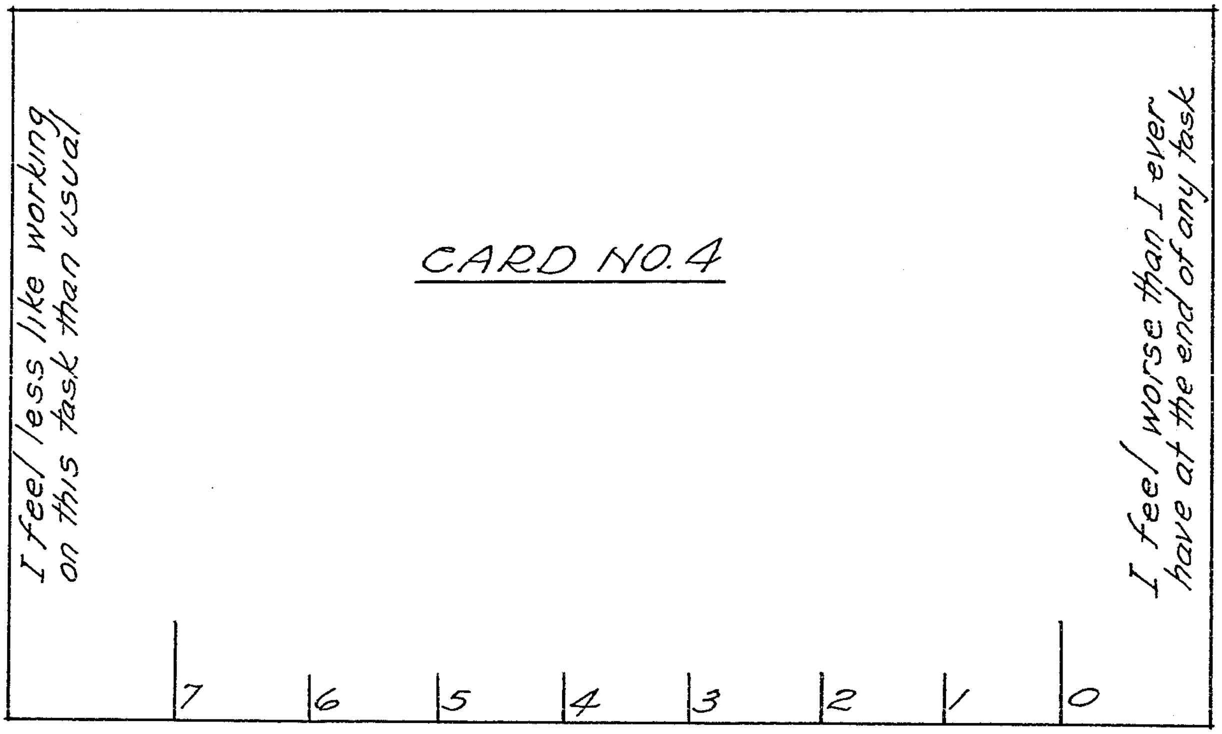
CARD NO. 2

I feel more like working on this task than I usually do

I feel worse than I ever have at the end of any task

9	8	7	6	5	4	3	2	1	0


CARD NO.3
I feel just about as much like working at this task as usual
I feel worse than I ever have at the end of any task
8
7
6
5
4
3
2
1
0


CARD NO.4
I feel less like working on this task than usual
I feel worse than I ever have at the end of any task
7
6
5
4
3
2
1
0

INSTRUCTIONS FOR USING THE FEELING TONE SCALE

On each of these four cards is drawn a feeling tone scale. That is to say, the line on the card represents the varying degrees of "feeling for work" which it is possible for you to experience during the working period which you will begin in a few moments. You will notice the line is graduated to show different degrees of change as they occur.

As you know, judgment as to how we feel during this given work period is dependent on how these "feelings for work" compare with feelings during work periods in the past. That is the reason the last point on the scale is described as "feeling worse at the end of this task than I have at the end of any task I have ever done".

Then, too, at different times you feel more like beginning work than you do at others. So if you feel more like working at this task than any other you've ever tried you select card No. 1. If you feel more like working on this task than you usually do, select card No. 2. If you feel just about as much like working as usual, select card No. 3. If you feel less like working than usual, select card No. 4.

Individuals selecting card No. 1 who also find it necessary to check the zero point on the scale at the end of the work period will have experienced a much greater change in feelings for work than those with card No. 4 who check the zero.

Now for the marking of the card. I will check the card according to your instructions. Selection of card No. 1 is the same as checking point 10 at the beginning of the task. Selection of card No. 2 is the same as checking point 9.

At certain intervals during the work period you will hear me say, "feeling". The moment you hear the word "feeling" you will name the number on the scale which you wish me to check. It will be the number which best describes your <u>feeling for work</u> at the moment. If your <u>feeling for work</u> has not changed since the previous check-up, the same number will again be checked. If your <u>feeling for work</u> has changed, the number you tell me to check will again indicate how far from the <u>beginning feeling</u> and from the <u>ending feeling</u> your <u>present feeling</u> is.

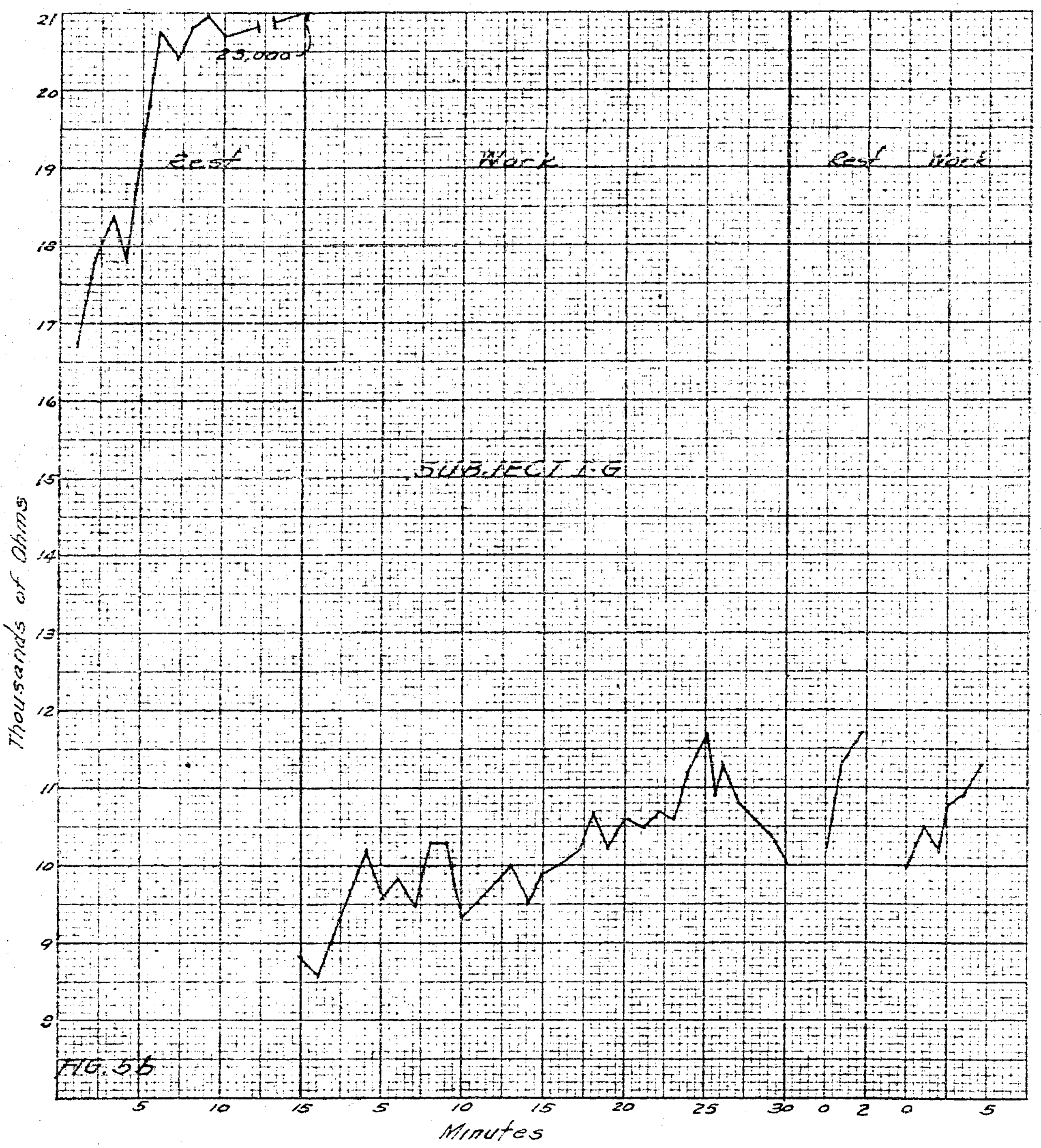
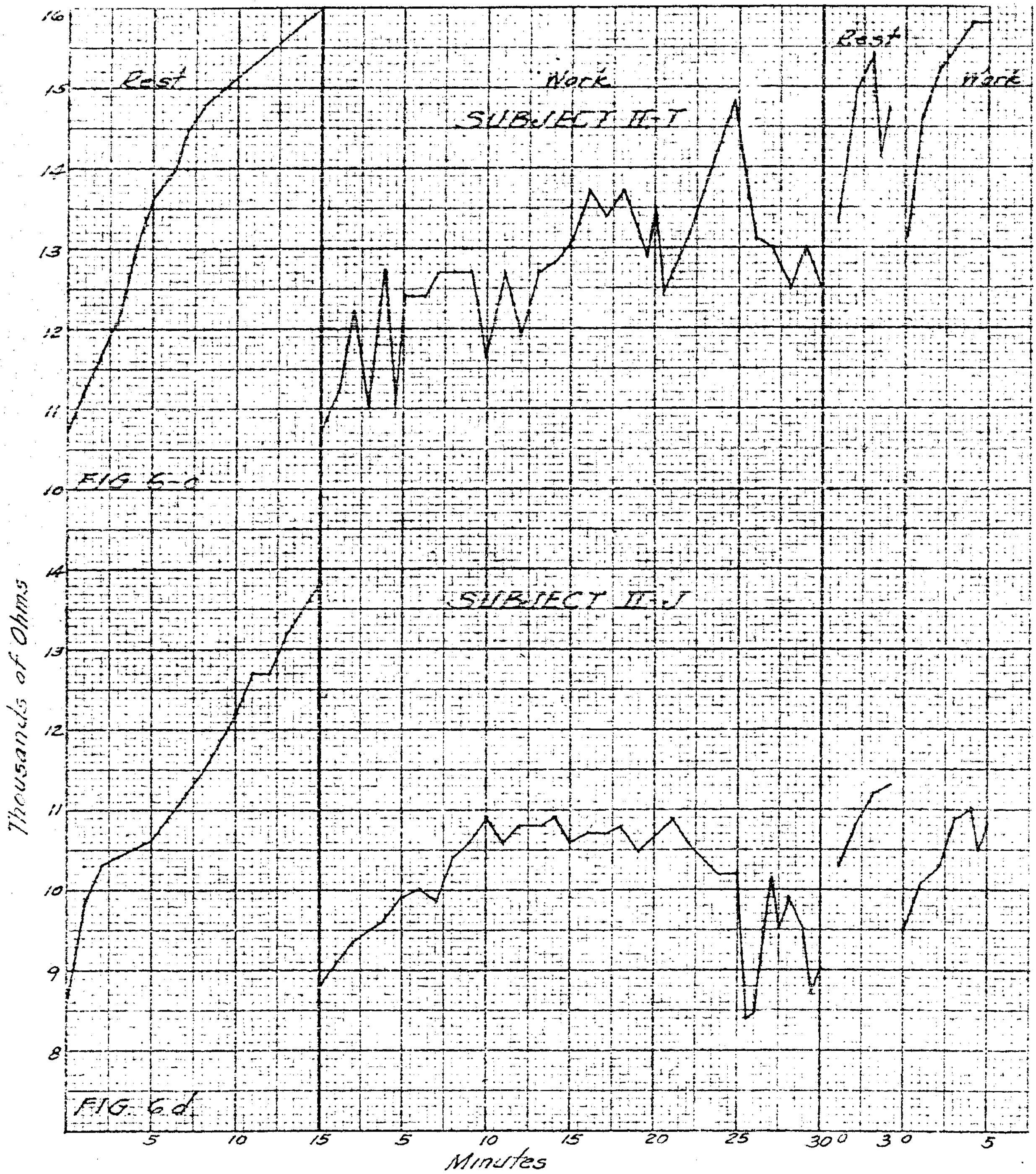
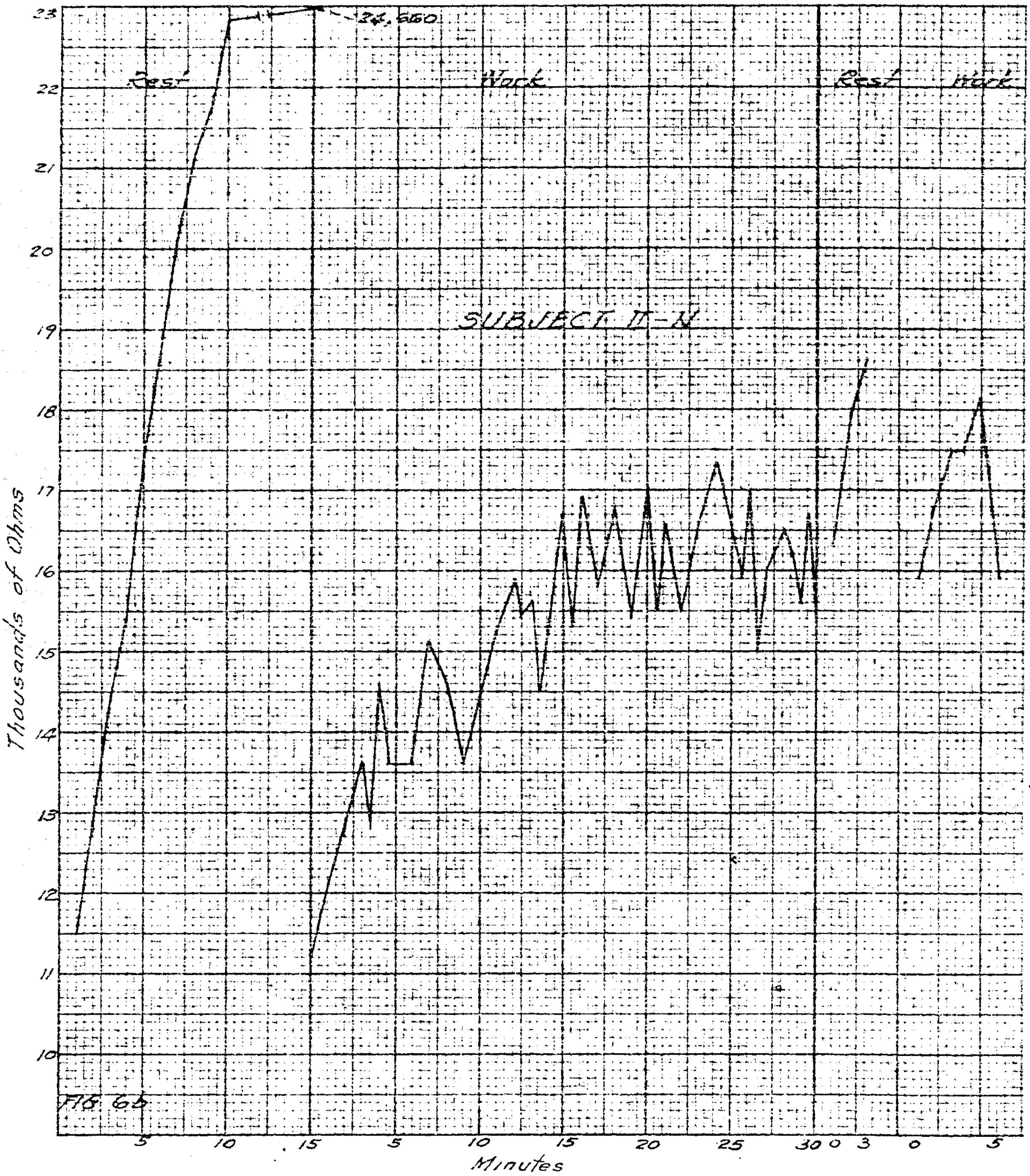

21
20
19
18
17
16
15
14
13
12
11
10
9
8
Thousands of Ohms
23,000
Rest
Work
Rest
Work
SUBJECT F.G
5
10
15
5
10
15
20
25
30
0
2
0
5
Minutes

FIG. 5b


Rest
Work
SUBJECT II-T
Rest
Work
FIG. 6-c
SUBJECT II-J
FIG. 6 d
Thousands of Ohms
Minutes


23
22
21
20
19
18
17
16
15
14
13
12
11
10
24,660
Rest
Work
Rest
Work
SUBJECT II-N
Thousands of Ohms
FIG. 6b
5
10
15
5
10
15
20
25
30
0
3
0
5
Minutes

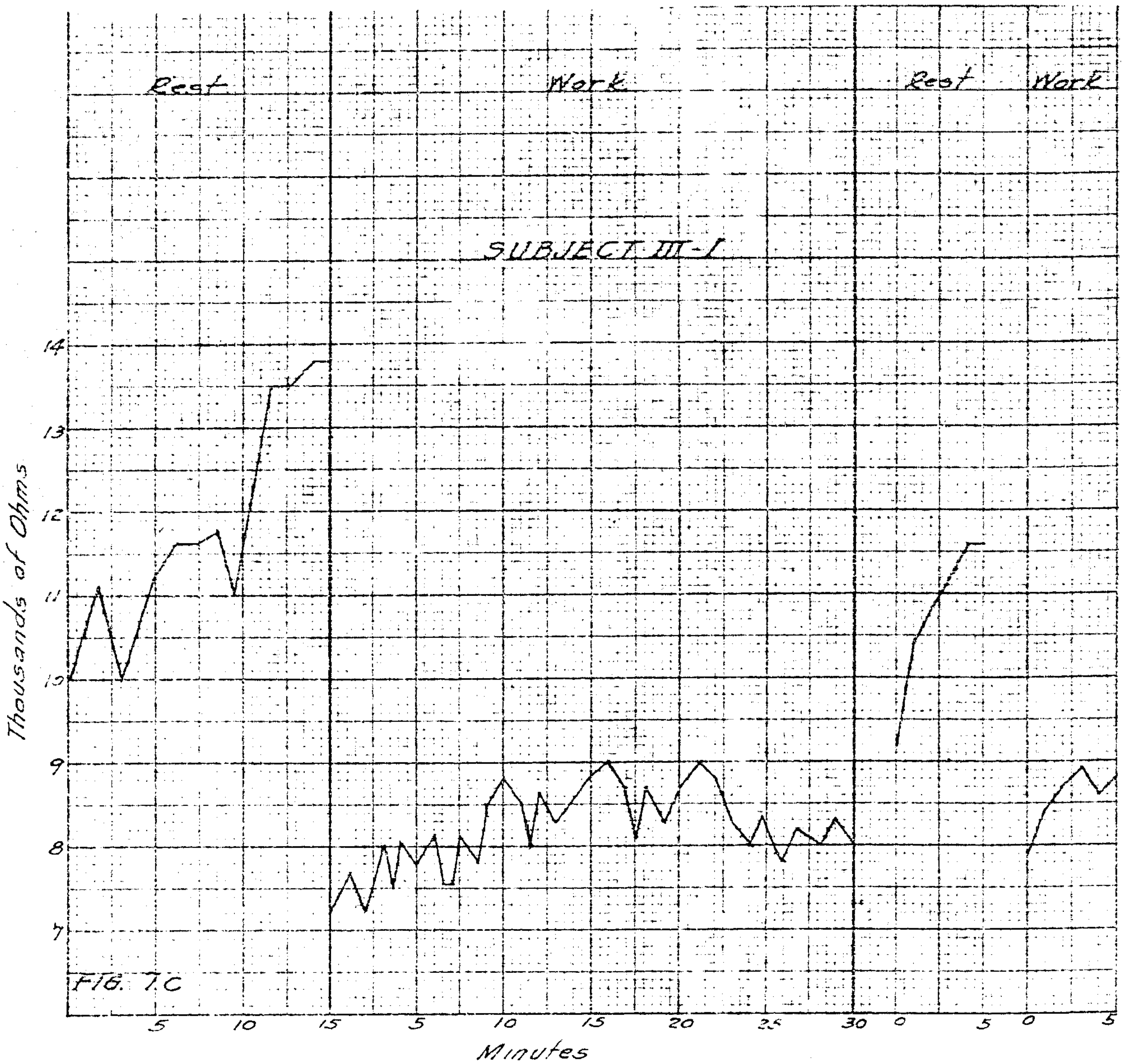

Rest
Work
Rest
Work
SUBJECT III-I
Thousands of Ohms
14
13
12
11
10
9
8
7
5
10
15
5
10
15
20
25
30
0
5
0
5
Minutes

FIG. 7 C

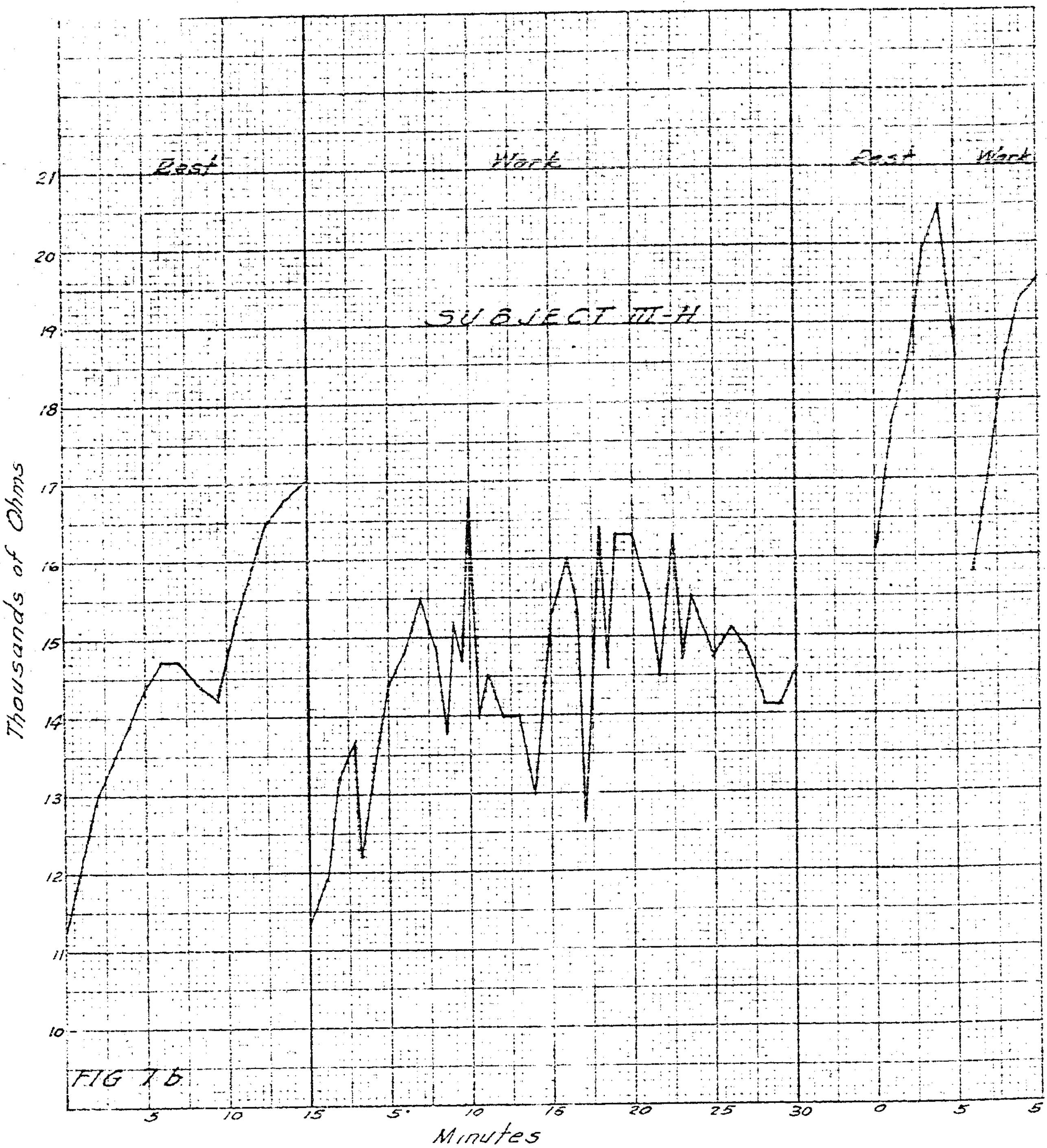

Rest
Work
Rest
Work
SUBJECT III-H
Thousands of Ohms
21
20
19
18
17
16
15
14
13
12
11
10
5
10
15
5
10
15
20
25
30
0
5
5
Minutes

FIG 7 b

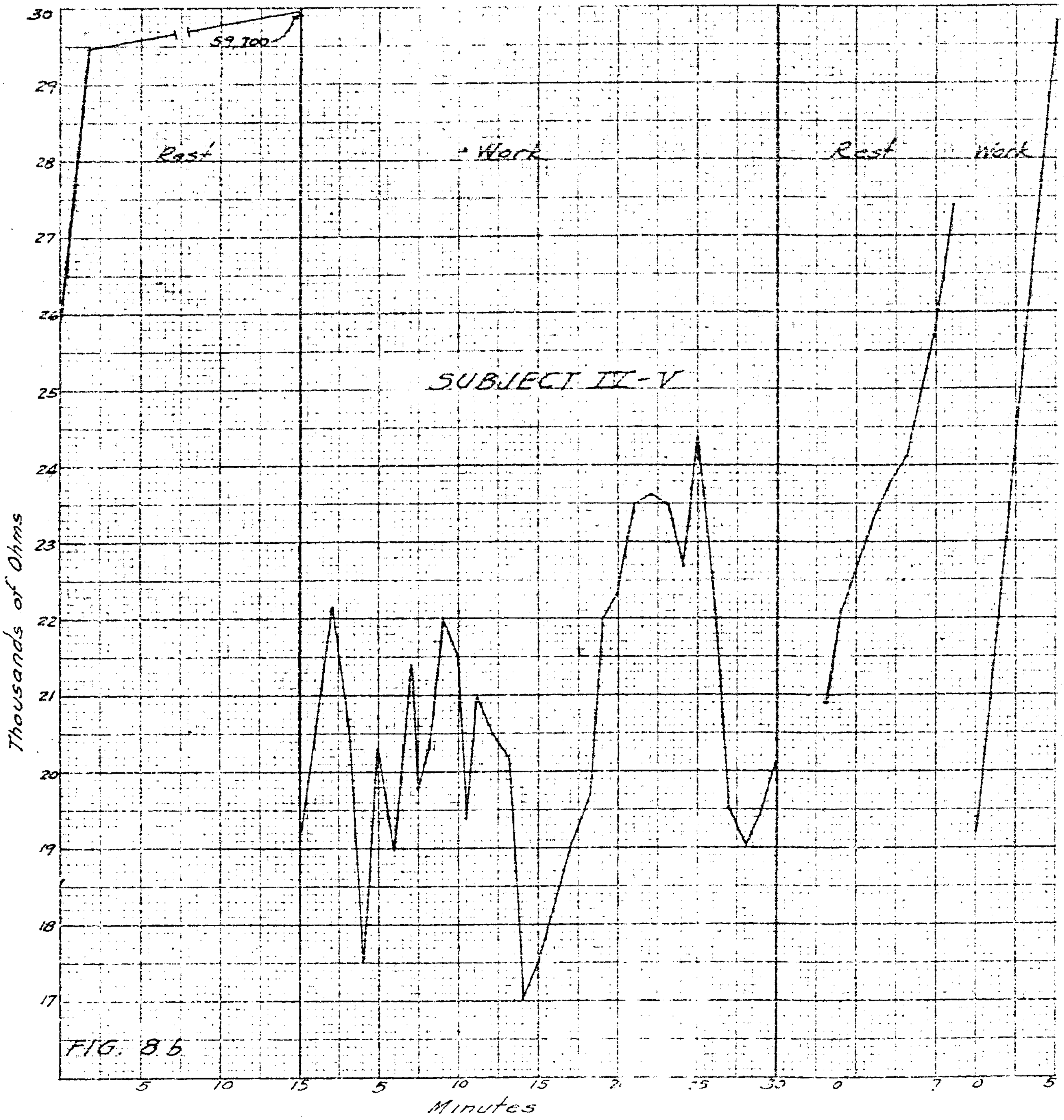

Thousands of Ohms
30
29
28
27
26
25
24
23
22
21
20
19
18
17
59,700
Rest
Work
Rest
Work
SUBJECT II-V
5
10
15
5
10
15
0
7
0
5
Minutes

FIG. 8 b

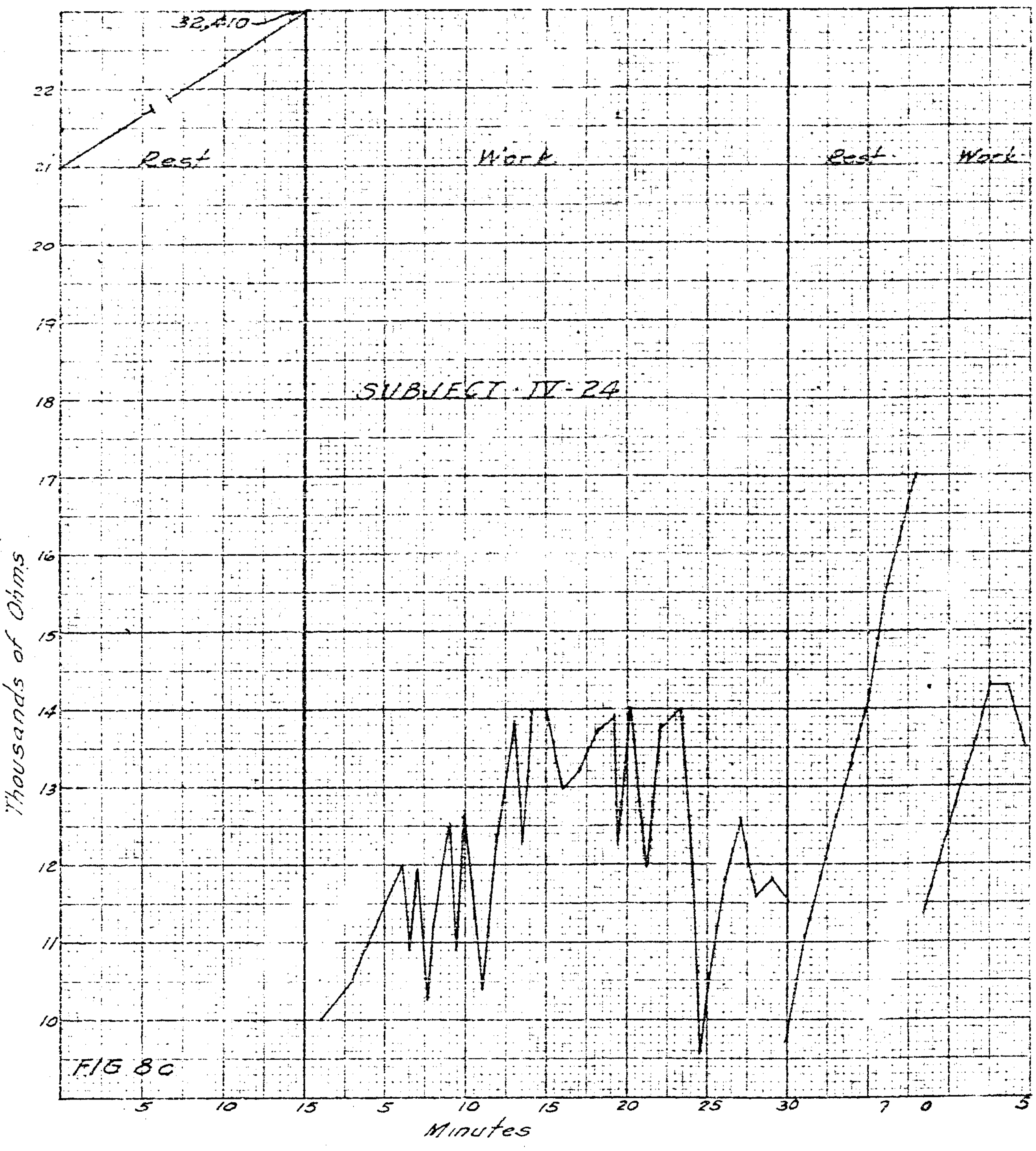
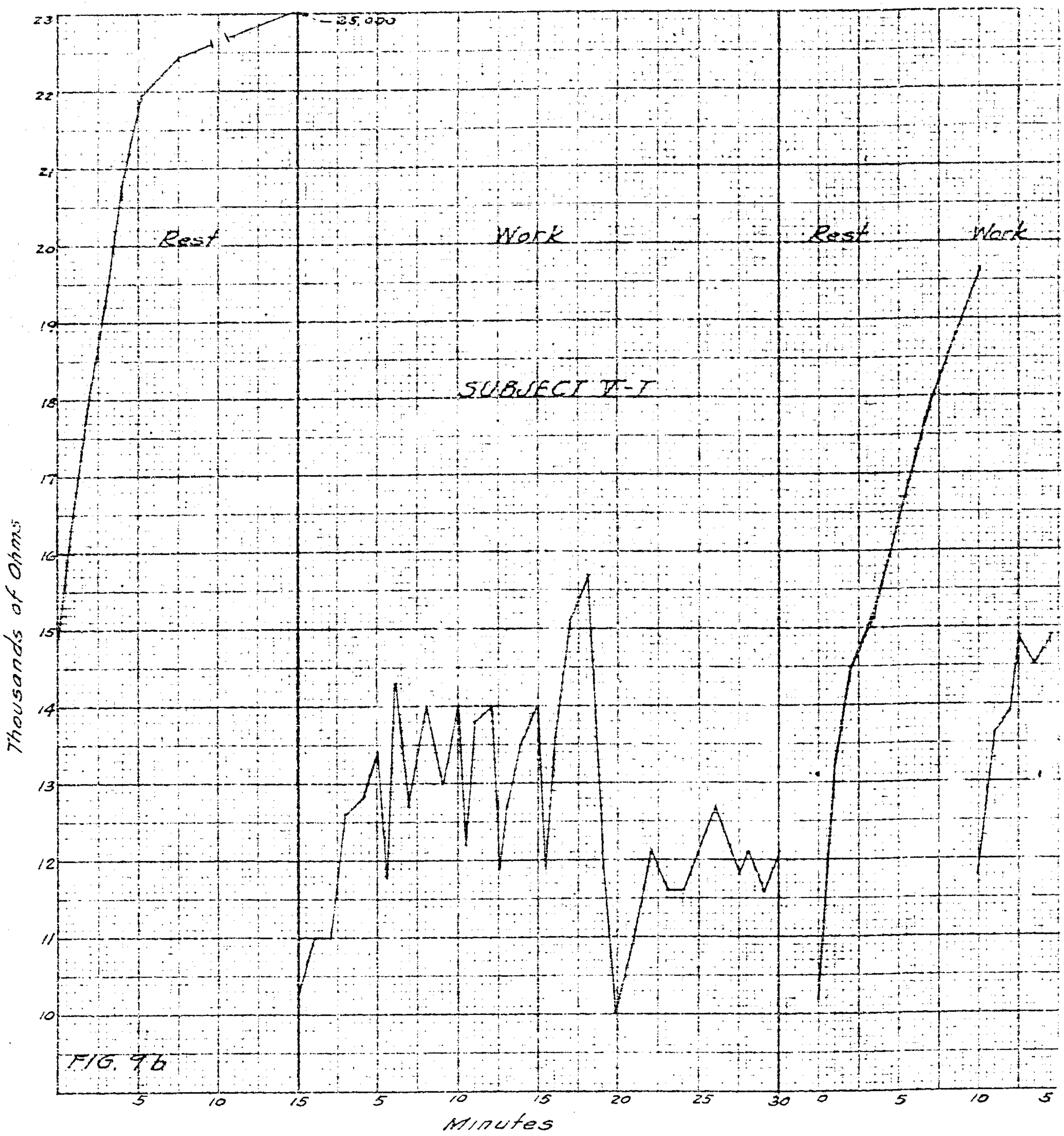

32,410
Rest
Work
Rest
Work
SUBJECT · IV - 24
Thousands of Ohms
22
21
20
19
18
17
16
15
14
13
12
11
10
5
10
15
5
10
15
20
25
30
7
0
5
Minutes

FIG 8c



23
22
21
20
19
18
17
16
15
14
13
12
11
10
—25,000
Rest
Work
Rest
Work
SUBJECT V-T
Thousands of Ohms
5
10
15
5
10
15
20
25
30
0
5
10
5
Minutes

FIG. 9b

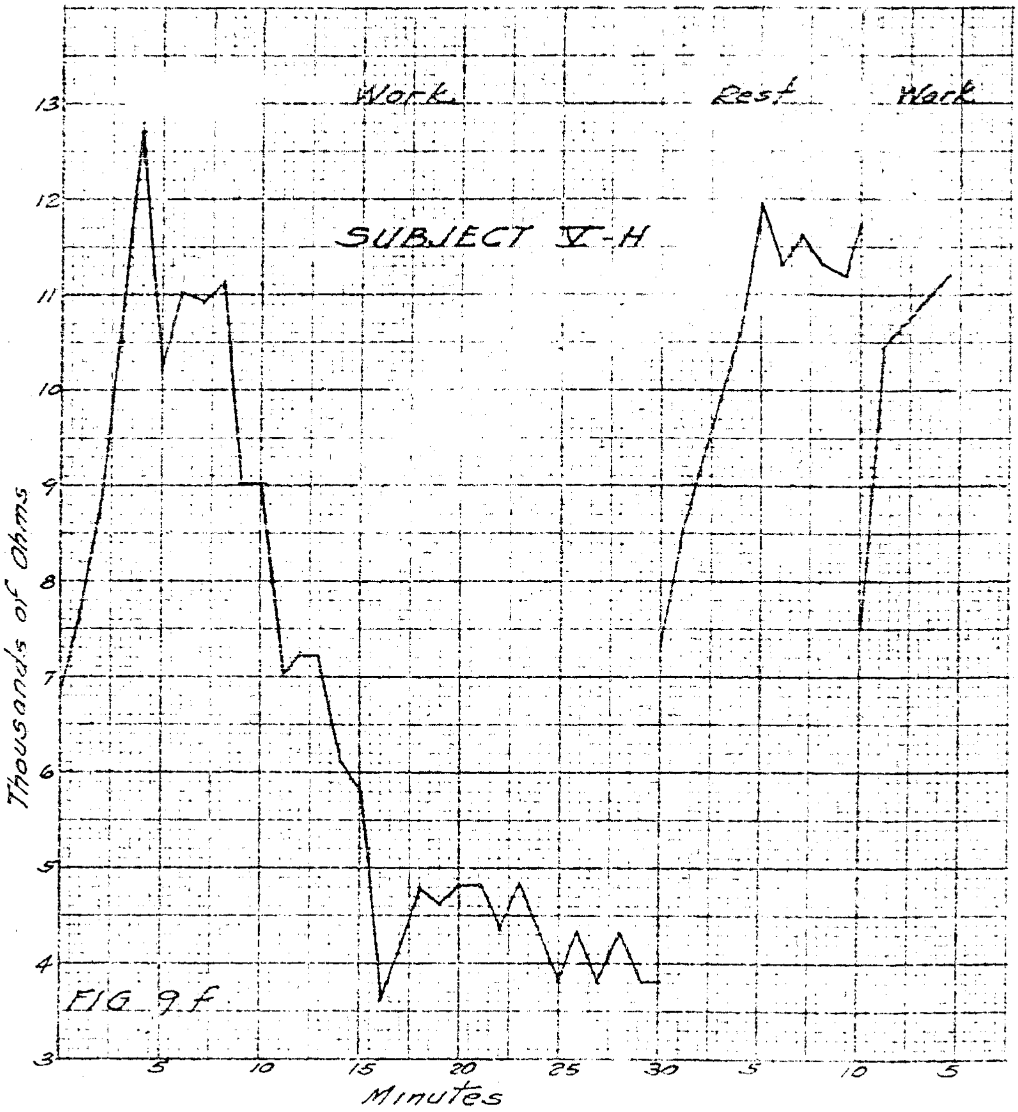

Work
Rest
Work
SUBJECT V-H
Thousands of Ohms
13
12
11
10
9
8
7
6
5
4
3
5
10
15
20
25
30
5
10
5
Minutes

FIG 9 f

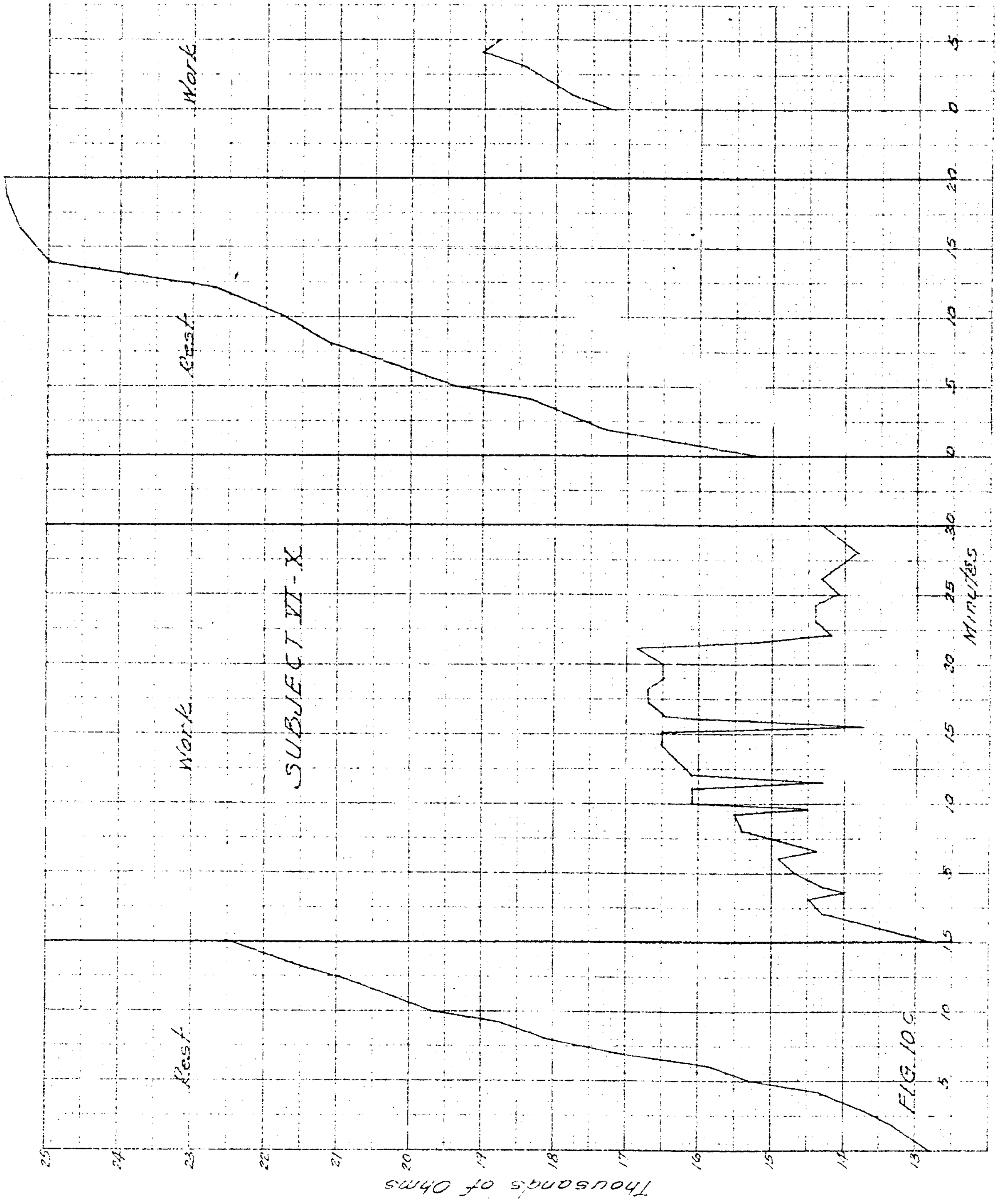

Rest
Work
Rest
Work
SUBJECT XI-X
Minutes
Thousands of Ohms
25
24
23
22
21
20
19
18
17
16
15
14
13

FIG. 10 C

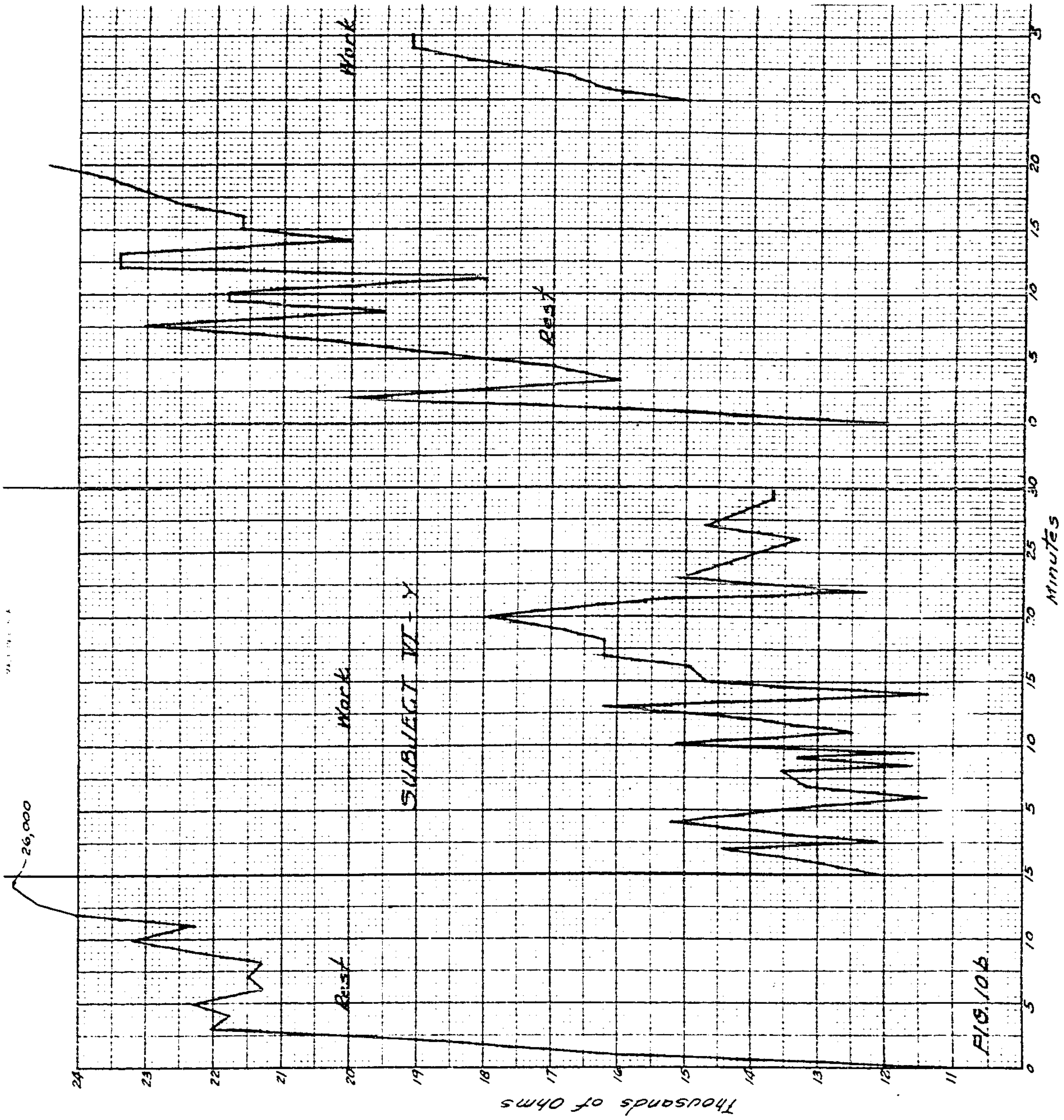

26,000
Rest
Work
SUBJECT VI-Y
Work
Rest
Minutes
Thousands of ohms

FIG. 10b

APPENDIX B

A STUDY OF THE WECHSLER PSYCHOGALVANOGRAPH

A STUDY OF THE WECHSLER PSYCHOGALVANOGRAPH

Introductory Statement - Comparison of the wiring diagrams of the Darrow "Behavior Resistance Box" and the "Wechsler Psychogalvanograph" prompted experimental investigation of the latter. See page of the experiment proper for pictures of these diagrams.

Approaches to the Problem - Two different approaches to the problem were used, the "constant sensitivity plan" and the "constant calibration plan". The former consisted in establishing empirically that sensitivity for a series of workable basic resistances which would allow scale differentiations per 1000 ohm change from initial resistance that were not too crude. Scale deflections must at the same time be kept small enough to prevent the indicator from jumping off the scale. According to the "constant calibration plan" a uniform scale deflection per 1000 ohm change from initial resistance would be established for all subjects regardless of their basic resistance.

Results of the Constant Sensitivity Plan - As an aid to the interpretation of the statement of results, let it be understood, that, for reliable calibration, at a given sensitivity, the mm. deflection on the galvanometer scale, per 1000 ohms, should vary in true inverse proportion to the magnitude of the resistance. This is the condition when the intensity of the current in the circuit is held constant. Evidence that this did not occur during this preliminary investigation can be had by referring to Table I. A resistance box was used in the circuit to obtain the data for the table. The table reveals, for example, a deflection of 2 mm. per 1000 ohms from a 40000 ohm basic resistance and

TABLE I

DEFLECTIONS ON GALVANOMETER SCALE IN MILLIMETERS

FOR CHANGES AS SHOWN

(RESISTANCE BOX USED FOR SUBJECT)

Base Resistance Ohms	Balance on Scale	Sensitivity	Changes in Resistance Box in Ohms				
			100	500	1000	2000	3000
6000	18.0	2	4.00	18.00	43.0	O.S.	O.S.
	16.0	4	6.00	33.0	O.S.		
	16.0	6	9.00	40.0	O.S.		
8000	16.0	2	1.25	8.0	18.0	42.0	O.S.
	16.0	4	3.75	20.0	O.S.	O.S.	
	16.0	6	6.0	28.0	O.S.		
10000	16.0	2	6.5	2.5	5.5	23.0	33.0
	17.5	4	2.0	15.0	26.0	O.S.	
	19.0	6	4.0	19.0	40.0	O.S.	
16000	16.0	2	0.5	2.5	4.0	8.0	13.0
	17.0	4	1.5	6.0	13.0	27.0	43.0
	18.0	8	2.0	12.0	24.0	O.S.	
20000	16.0	2	0.25	1.0	2.0	3.0	5.0
	17.0	4	0.50	3.0	8.0	17.0	26.0
	19.0	8	1.50	8.0	18.0	37.0	O.S.
30000	16.0	2	0.0	0.0	1.0	2.0	3.0
	18.0	4	0.5	2.0	3.0	6.0	11.0
	20.0	8	1.5	3.5	7.5	16.5	26.0
40000	16.0	2	0.0	0.25	0.75	1.0	1.75
	17.0	4	0.25	0.75	2.00	4.5	7.00
	20.0	8	0.00	3.00	5.50	11.0	17.0
60000	16.0	2	0.00	0.00	0.50	0.75	1.0
	16.0	4	0.00	0.00	1.00	2.00	3.00
	18.0	8	0.25	1.00	2.50	5.00	8.00
80000	16.0	2	0.00	0.00	0.25	0.50	0.75
	16.5	4	0.00	0.25	0.50	1.00	1.50
	17.5	8	0.00	0.25	1.50	2.50	4.00
	18.0	10	0.25	0.75	1.75	3.25	5.00
90000	15.5	2	0.00	0.00	0.00	0.00	0.00
	16.0	4	0.00	0.25	0.25	0.50	1.25
	17.5	8	0.25	0.50	1.00	2.50	3.50
	18.0	10	0.00	0.75	1.50	3.00	4.50

O.S. means indicator went off scale here a 26 mm. deflection per 1000 ohms from a 10000 ohm basic resistance. If the inverse proportion had held true the deflection at the 10000 ohm base should have been four times two or eight mm. instead of the twenty-six mm. Thus the effect of a variable current in the circuit has been demonstrated when an easily manipulated and controllable resistance box was used in the circuit. What would be the effect of this inconstant current when a variable human resistor is substituted in the current? To answer this question changes in resistance level were measured for ten subjects submitted to approximately the same conditions as in the experiment proper. Results of these observations are presented in Tables II and III. The data in the tables show for the ten subjects investigated

1. A marked difference in the same subject in resistance between the beginning and end of a continuous work period. In subject A, it is seen, the initial resistance was 40000 ohms (numbers were rounded for convenience) and the final resistance was 10000. In terms of scale deflections, a change occurred from 2 mms. per 1000 ohms for the beginning readings to 26 mms. per 1000 ohms for final readings.

2. A marked difference in initial resistance between subjects. For example, 40000 ohms for subject F as compared with 10000 ohms for subject I. See the foregoing for difference in scale deflections.

3. These differences shown for the same subjects as well as those shown between subjects closely approximate those in Table I, which it will be recalled was constructed with a resistance box in the circuit. That is to say, the unit of measure on the galvanometer scale for a 1000 ohm resistance change varied continuously during a given experimental sitting and from one experimental sitting to another.

Resistance readings based on such unstable quantitative units

TABLE II

CHANGES IN OHMS OF RESISTANCE RESULTING FROM VARYING STIMULI

AT VARYING SENSITIVITIES

Subject	Basic Resistance in Ohms	Sensitivity Used	Resistance in Ohms after			Resistance in Ohms	
Sex			Straightening up & picking up Stylus	Exp. uncovers Task	Punching Board at leisurely Rate	3 Min. Rest	5 Min. Rest
A - F	30000	3	23900				
B - F	23000	8	22400				
C - F	24000	8			18600		
D - F	23700	8			13800		
E - M	42000	4	40000		11600	12500	14000
F - M	27000	4		22000	7000	7600	7700
G - M	6100	4		5500	5200	5300	5400
H - F	8900 to 12600	4		12100	11200	11300	11300
I - F	15200	4	14000	12200	9400	9400	8600
J - F	8700	4	7700	6700	6300	6600	7100

TABLE III

COMPARISON OF DEFLECTIONS FROM INITIAL BASE AND FROM FINAL BASE RESULTING

FROM 1000 OHM CHANGE AT SENSITIVITY OF 4

Subject	*Approximate Initial Base	Deflection in Mm. for 1000 Ohm Change	Approximate Final Base	Deflection in Mm. for 1000 Ohm Change
E	40000	2	10000	26
F	20000	8	8000	off scale
I	16000	13	10000	26

*Base given in round nos. for convenient check with Table I of measure are neither comparable at various periods for the same subject nor from subject to subject. The constant sensitivity plan had, therefore, to be discarded.

Results of the Constant Calibration Plan - As assurance that the unreliable calibrations were not a function of the special technique employed, the so-called constant calibration plan was substituted for the constant sensitivity plan. According to this method a given distance on the scale is selected to represent a change of 1000 ohms from initial resistance regardless of the basic resistance of the subjects. That is to say, scale calibration was held constant from subject to subject. In accordance with expectancy, to allow the same amount of current to flow through the galvanometer at a relatively low basic resistance, as at a relatively high basic resistance sensitivity must be low in the former case and high in the latter. The constant calibration plan could have been termed, therefore, the "change-in-sensitivity plan".

Keeping calibrations constant necessitates varying sensitivity. Varying sensitivity is practicable with the easily controllable resistance box in the circuit. However, substituting for the non-variable resistor, the subject (variable resistance) so complicates the problem that one experimenter could not vary sensitivity fast enough to keep pace with changing resistances. It was for this reason, among others, that Darrow by the simple throwing of a switch takes the subject (variable resistance) temporarily out of the circuit, and substitutes for him a non-variable resistance while making his calibration. The experimenter of the present investigation had also to keep continuous records of resistance changes as they occurred.

In addition, fluctucations in resistance levels are not only a function of variations in the subject's response, but are inherent in the calibration process itself. It was observed in Table I that a different basic resistance accompanied each change in sensitivity. Attention has already been called to the positive relationship between changes in sensitivity and refinement in measurement.

The foregoing two reasons may be summarized briefly as follows: Fluctuations in resistance levels paralleling changes in the subjects are overlapped by fluctuations due to sensitivity changes.

Having in mind the disadvantages of the Wechsler circuit as demonstrated by attempts to secure comparable scale calibrations, any modifications made in the circuit must secure, therefore,

1. Uniform sensitivity
2. Uniform calibrations
3. Uniform and small current through subjects

As has been pointed out, the Darrow circuit accomplishes these three objectives by holding resistance constant in three arms of the bridge, with a variable resistance in the fourth or subject's arm of the bridge. By substituting in the subject's arm of the Wechsler circuit a 99000 ohm resistor bank, and keeping the actual resistance in the fourth arm of the bridge constant at 9990 ohms, the essential features of the Darrow circuit were met. With the increased resistance the 1-1/2 volt dry cell originally in the circuit was replaced by a 3 volt dry cell.

TABLE IV

CALIBRATION CHART FOR PSYCHOGALVANOGRAPH

(Shunt sensitivity equals 40)

Deflection Readings in mm.	Ohmic Changes
1.0	130
2.0	260
3.0	500
4.0	660
5.0	820
6.0	1000
7.0	1160
8.0	1290
9.0	1320
10.0	1600
11.0	1800
12.0	1950
13.0	2125
14.0	2275
15.0	2450
16.0	2600
17.0	2800
18.0	2950
19.0	3075
20.0	3300
21.0	3450
22.0	3625
23.0	3800
24.0	3950
25.0	4125
26.0	4350
27.0	4475
28.0	4625
29.0	4775
30.0	4950
40.0	6600
50.0	8250
60.0	9650

APPENDIX C

COMPUTATION OF THE REGRESSION LINE OF BEST FIT

TABLE I A

DEVIATIONS AND DEVIATIONS SQUARED FROM AN ASSUMED MEAN OF 60 FOR THE OBSERVATIONS IN CONDITIONS I, II, AND III

Condition I - 2 Minutes			Condition II - 3 Minutes			Condition III - 5 Minutes		
Recovery Ratio	d^1	$(d^1)^2$	Recovery Ratio	d^1	$(d^1)^2$	Recovery Ratio	d^1	$(d^1)^2$
53.8	- 6.2	38.44	46.2	-13.8	190.44	20.0	-40.	1600.
46.7	- 13.3	176.78	39.1	-20.9	436.81	90.0	30.	900.
60.0	0	0	33.3	-26.7	712.89	125.0	65.	4225.
59.1	- .9	.81	25.0	-35.	1225.	33.3	-26.7	712.89
- 9.1	- 69.1	4774.81	77.8	17.8	316.84	75.0	15.	225.
45.0	- 15.0	225.	8.3	-51.7	2672.89	100.0	40.	1600.
85.7	25.7	660.49	100.0	40.	1600.	100.0	40.	1600.
-20.0	- 80.0	6400.	77.8	17.8	316.84	91.0	31.	961.
23.1	- 36.9	1361.61	33.3	-26.7	712.89	57.1	- 2.9	8.41
33.3	- 26.7	712.89	28.6	-31.4	985.96	50.0	-10.	100.
55.0	- 5.0	25.	9.1	-50.9	2590.81	100.0	40.	1600.
16.7	- 43.3	1874.89	109.0	49.	2401.	92.8	32.8	1075.84
66.7	6.7	44.89	53.0	- 7.	49.	50.0	-10.	100.
15.8	- 44.2	1953.64	70.4	10.4	1108.16	60.0	0	0
77.8	17.8	316.84	200.0	140.	19600.	33.3	-26.7	712.89
60.0	0	0	59.1	- .9	.81	63.6	3.6	12.96
0	- 60.	3600.	140.	80.	6400.	0	-60.	3600.
-12.5	- 72.5	5256.25	40.0	-20.	400.	80.0	20.	400.
26.7	- 33.3	1108.89	60.0	0	0	61.5	1.5	2.25
66.7	6.7	44.89	46.2	-13.8	190.44	60.0	0	0
58.3	- 1.7	2.89	100.0	40.0	1600.	116.8	56.8	3226.24
36.4	- 23.6	556.96	0	-60.	3600.	40.0	-20.	400.
40.0	- 20.	400.	109.0	49.	2401.	86.6	26.6	707.56
-11.1	- 71.1	5055.21	44.4	-15.6	243.36	128.0	68.	4624.
45.5	- 14.5	210.25	41.2	-18.8	353.44	107.7	47.7	2275.29
Summation	-580.4	34801.54		50.8	49108.58		321.7	30669.33
							d^1	$(d^1)^2$

TABLE I B

DEVIATIONS AND DEVIATIONS SQUARED FROM AN ASSUMED MEAN OF 60 FOR THE OBSERVATIONS IN CONDITIONS IV, V, AND VI

Condition IV - 7 Minutes			Condition V - 10 Minutes			Condition VI - 20 Minutes		
Recovery Ratio	d^1	$(d^1)^2$	Recovery Ratio	d^1	$(d^1)^2$	Recovery Ratio	d^1	$(d^1)^2$
66.7	6.7	44.89	71.4	11.4	129.96	30.0	- 30.0	900.00
50.0	-10.	100.	31.3	- 28.7	823.69	16.7	- 43.3	1874.89
125.0	65.	4225.	36.4	- 23.6	556.96	57.1	- 2.9	8.41
57.1	- 2.9	8.41	73.7	13.7	187.69	42.9	- 17.1	292.41
100.0	40.	1600.	37.5	- 22.5	506.25	87.5	27.5	756.25
122.2	62.2	3868.84	40.0	- 20.	400.	3.8	- 56.2	3158.44
136.3	76.3	5821.69	22.2	- 37.8	1428.84	30.0	- 30.	900.
71.4	11.4	129.96	0	- 60.	3600.	50.0	- 10.	100.
100.0	40.	1600.	63.6	3.6	12.96	8.3	- 51.7	2672.89
57.1	- 2.9	8.41	0	- 60.	3600.	46.2	- 13.8	190.44
60.0	0	0	62.5	2.5	6.25	0	- 60.	3600.
100.0	40.	1600.	85.7	25.7	660.49	104.9	44.9	2016.01
81.3	21.3	453.69	88.9	28.9	835.21	5.3	- 54.7	2992.09
61.9	1.9	3.61	56.0	- 4.	16.	37.5	- 22.5	506.25
110.0	50.	2500.	20.0	- 40.	1600.	75.9	15.9	252.81
107.8	47.8	2284.84	0	- 60.	3600.	0	- 60.	3600.
83.4	23.4	547.56	80.0	20.	400.	75.0	15.	225.
75.0	15.	225.	18.2	- 41.8	1747.24	69.2	9.2	84.64
62.5	2.5	6.25	17.6	- 42.4	1797.76	50.0	- 10.	100.
60.0	0	0	111.1	51.1	2611.21	33.3	- 26.7	712.89
66.7	6.7	44.89	112.5	52.5	2756.25	42.9	- 17.1	292.41
76.0	16.	256.	133.3	73.3	5372.89	50.0	- 10.	100.
88.9	28.9	835.21	50.0	- 10.	100.	12.5	- 47.5	2256.25
100.0	40.	1600.	50.0	- 10.	100.	22.7	- 37.3	1391.29
100.0	40.	1600.	70.0	10.	100.	100.0	40.	1600.
Summation	619.3	29364.25		-168.1	32949.65		-448.3	30583.37

COMPUTATION OF THE SUM OF (DEVIATIONS)^2 FOR EACH OF THE ARRAYS (CONDITIONS)

$$\frac{\Sigma d^2}{N} = \frac{\Sigma (d^1)^2}{N} - \left(\frac{\Sigma d^1}{N}\right)^2$$

$$\Sigma d^2 = \Sigma (d^1)^2 - \frac{(\Sigma d^1)^2}{N}$$

Condition	N	Σd^1	$\Sigma (d^1)^2$	$\frac{\Sigma d^1}{N}$	m_a	$(\Sigma d^1)^2$	$\frac{(\Sigma d^1)^2}{N}$	Σd^2
2	25	-580.4	34801.54	-23.216	36.784	336864.16	13474.56	21326.98
3	25	50.8	49108.58	2.032	62.032	2580.64	103.23	49005.35
5	25	321.7	30669.33	12.868	72.868	103490.89	4139.64	26529.69
7	25	619.3	29364.25	24.772	84.772	383532.49	15341.30	14022.95
10	25	-168.1	32949.65	- 6.724	53.276	28257.61	1130.30	31819.35
20	25	-448.3	30583.37	-17.932	42.068	200972.89	8038.92	22544.45
	150	-205.0	207476.72	*- 1.367	*58.633	*42025.00	*280.17	165248.77

COMPUTATION OF THE SUM OF (DEVIATIONS)^2 BETWEEN THE ARRAYS

$$M_a = M_x - \frac{d^1}{N}$$

$M_x = 60$

$M_a = 60 - (-1.367)$

$M_a = 58.633$

Condition	$m_a - M_a$	$(m_a - M_a)^2$
2	-21.849	477.378803
3	3.399	11.553201
5	14.235	202.635225
7	26.139	683.247321
10	- 5.357	28.697449
20	-16.565	274.399225
Total		1677.911224

Σd^2 (all items about M_a) $= \Sigma (d^1)^2 - \frac{(\Sigma d^1)^2}{N}$

$= 207476.72 - 280.17 = 207196.55$

Σd^2 (all items about m_a's) $= 165248.77$

Σd^2 (m_a's about M_a) $= 41947.78$

*These are not totals

$\Sigma n(m_a - M_a)^2 = 25 \times 1677.9112$
$= 41947.78$

Check:-
$165248.77 + 41947.78 = 207196.55$

TEST OF EXISTENCE OF CORRELATION

Nature of Variability	Within Arrays	Between Arrays
Degrees of Freedom	144	5
Sum of $(\text{deviations})^2$	165248.77	41947.78
Mean Variance	1147.5609	8389.556
Log of Mean Variance Base 10	3.05977	3.92374
Log of Mean Variance Base e ($\log_{10} N \times 2.3025851$)	7.04538	9.03475

$$z = \tfrac{1}{2}(9.03475 - 7.04538) = 0.99468$$

Conclusion:
The hypothesis of no correlation is untenable.

FITTING OF FIRST DEGREE EQUATION

X	Y	x	xY	x^2	Yc	x^2Y	x^4	x^3
2	36.784	-8	-294.272	64	63.011360	2354.176	4096	-512
3	62.032	-7	-434.224	49	62.260841	3039.568	2401	-343
5	72.868	-5	-364.340	25	60.759803	1821.700	625	-125
7	84.772	-3	-254.316	9	59.258765	762.948	81	- 27
*10	53.276	0	0	0	57.007208	0	0	0
20	42.068	10	420.680	100	49.502018	4206.800	10000	1000
Totals	351.800	-13	-926.472	247		12185.192	17203	- 7

$\Sigma Y = Na + b\Sigma x$

$\Sigma xY = a\Sigma x + b\Sigma x^2$

$351.800 = 6a - 13b$

$-926.472 = -13a + 247b$

$\underline{6684.200 = 114a - 247b}$

$5757.728 = 101a$

$a = 57.007208$

$13b = 342.043248 - 351.800$

$13b = -9.756752$

$b = -0.750519$

$Y_c = 57.007208 - 0.750519x$

*Used as origin

Condition	m_a	Y_c	(m_a-Y_c)	$(m_a-Y_c)^2$	(Y_c-M_a)	$(Y_c-M_a)^2$
2	36.784	63.011	-26.227	687.855529	4.378	19.166884
3	62.032	62.261	- .229	0.052441	3.628	13.162384
5	72.868	60.760	12.108	146.603664	2.127	4.524129
7	84.772	59.259	25.513	650.913169	0.626	0.391876
10	53.276	57.007	- 3.731	13.920361	-1.626	2.643876
20	42.068	49.502	- 7.434	55.264356	-9.131	83.375161
	Totals			1554.609520		123.264310
	25 X Totals			38865.2375		3081.6075

Check:-

$\sum n(m_a-Y_c)^2 = 38865.24$
$\sum n(Y_c-M_a)^2 = 3081.61$
$\sum n(m_a-M_a)^2 = 41946.85$

TEST OF LINEAR CORRELATION

Nature of Variability	Within Arrays	Between Arrays
Degrees of Freedom	144	4
Sum of $(\text{deviations})^2$	165248.77	38865.24
Mean Variance	1147.5609	9716.31
Log of Mean Variance Base 10	3.05977	3.98750
Log of Variance Base e	7.04538	9.18156

$$z = \tfrac{1}{2}(9.18156-7.04538)$$
$$= \tfrac{1}{2}(2.13618)$$
$$= 1.06809$$

Conclusion:-

A first degree regression equation is not adequate for the expression of the law of relationship between ratios of recovery and minutes of rest.

FITTING OF SECOND DEGREE EQUATION

$$\Sigma Y = Na + b\Sigma x + c\Sigma x^2$$
$$\Sigma xY = a\Sigma x + b\Sigma x^2 + c\Sigma x^3$$
$$\Sigma x^2Y = a\Sigma x^2 + b\Sigma x^3 + c\Sigma x^4$$

$$351.800 = 6a - 13b + 247c$$
$$-926.472 = -13a + 247b - 7c$$
$$12185.192 = 247a - 7b + 17203c$$

$$4573.400 = 78a - 169b + 3211c$$
$$-5558.832 = -78a + 1482b - 42c$$

$$-985.432 = 1313b + 3169c$$

$$12185.192 = 247a - 7b + 17203c$$
$$-17602.968 = 247a + 4693b - 133c$$

$$-5417.776 = 4686b + 17070c$$

$$-4617734.352 = 6152718b + 14849934c$$
$$-7113539.888 = 6152718b + 22412910c$$

$$-2495805.536 = 7562976c$$

$$c = -0.33000310$$

$$1313b = -985.432 - 3169c$$

$$= -985.432 + 1045.7798239 = 60.34782390$$

$$b = 0.04596179$$

$$6a = 351.800 + 13b - 247c = 433.90827573$$

$$a = 72.318046$$

$$Y_c = 72.318046 + 0.04596179x - 0.33000310x^2$$

Condition	Y_c	m_a	Y_c used	m_a-Y_c	$(m_a-Y_c)^2$	(Y_c-M_a)	$(Y_c-M_a)^2$
-8	50.83015328	36.784	50.830	-14.046	197.290116	- 7.803	60.886809
-7	55.82616157	62.032	55.826	6.206	38.514436	- 2.807	7.879249
-5	63.83815955	72.868	63.838	9.030	81.540900	5.205	27.092025
-3	69.21013273	84.772	69.210	15.562	242.175844	10.577	111.872929
0	72.318046	53.272	72.318	-19.046	362.750116	13.685	187.279225
10	39.77735390	42.068	39.777	2.291	5.248681	-18.856	355.548736
			Totals		927.520093		750.558973
			25	Totals =	23188.0023		18763.9743

Check:-

$\Sigma n(m_a-Y_c)^2 = 23188.0023$

$\Sigma n(Y_c-M_a)^2 = \underline{18763.9743}$

$\Sigma n(m_a-M_a)^2 = 41951.9766$

TEST OF SECOND DEGREE REGRESSION EQUATION

Nature of Variability	Within Arrays	Between Arrays
Degree of Freedom	144	3
Sum of (deviations)^2	165248.77	23188.00
Mean Variance	1147.5609	7729.33
Log of Mean Variance Base 10	3.05977	3.88814
Log of Mean Variance Base e	7.04538	8.95277

$$z=\tfrac{1}{2}(8.95277-7.04538)=0.95370$$

Conclusion:-

A second degree regression equation is not adequate for the expression of the law of relationship between ratios of recovery and minutes of rest.

FITTING OF THIRD DEGREE EQUATION

$$\Sigma Y=Na+b\Sigma x+c\Sigma x^2+d\Sigma x^3$$
$$\Sigma xY=a\Sigma x+b\Sigma x^2+c\Sigma x^3+d\Sigma x^4$$
$$\Sigma x^2Y=a\Sigma x^2+b\Sigma x^3+c\Sigma x^4+d\Sigma x^5$$
$$\Sigma x^3Y=a\Sigma x^3+b\Sigma x^4+c\Sigma x^5+d\Sigma x^6$$

X	x	Y	xY	x^2	x^2Y	x^3	x^3Y	x^4	x^5	x^6
2	-8	36.784	-294.272	64	2354.176	-512	-18833.408	4096	-32768	262144
3	-7	62.032	-434.224	49	3039.568	-343	-21276.976	2401	-16807	117649
5	-5	72.868	-364.340	25	1821.700	-125	- 9108.500	625	- 3125	15625
7	-3	84.772	-254.316	9	762.948	- 27	- 2288.844	81	- 243	729
10	0	53.276	0	0	0	0	0	0	0	0
20	10	42.068	420.680	100	4206.800	1000	42068.000	10000	100000	1000000
Totals	-13	351.800	-926.472	247	12185.192	- 7	-9439.728	17203	47057	1396147

$$351.800=6a-13b+247c-7d$$
$$-926.472=-13a+247b-7c+1.7203d$$
$$12185.192=247d-7b+17203c+47057d$$
$$-9439.728=-7a+17203b+47057c+1396147d$$

$$58.633333=a-2.1666667b+41.166667c-1.1666667d$$
$$-71.267077=-a+19.000000b-0.5384615c+1323.3077d$$
$$49.332761=a-0.0283401b+69.647773c+190.51417d$$
$$-1348.5325=-a+2457.5714b+6722.4286c+199449.57d$$

$$-12.633744=16.833333b+40.628205c+1322.1410d$$
$$-21.934316=18.971660b+69.109311c+1513.8219d$$
$$-1299.1997=2457.5431b+6792.0764c+199640.08d$$

$$-0.7505194=b+2.4135567c+78.543031d$$
$$-1.1561622=b+3.6427656c+79.793856d$$
$$-0.5286580=b+2.7637670c+81.235673d$$

$$-0.4056428=1.2292089c+1.250825d$$
$$-0.6275042=-0.8789986c+1.441317d$$

$$-0.3300031=c+1.0175853d$$
$$-0.7138853=-c+1.6402950d$$

$$0.3838822=2.6578803d$$

$$d=0.1444317$$

$$c=-0.3300031-1.0175853d$$

$$b=-0.7505194-2.4135567c=78.543031d$$

$$=-0.7505194+1.1512055-11.3441035=-10.9434174$$

$$a=58.633333+2.1666667b-41.166667c+1.1666667d$$

$$=58.633333-23.7107372+19.6354586+0.1685037$$

$$a=54.7265584$$

$$Y_c=54.7265584-10.943417x-0.4769747x^2+0.1444317x^3$$

x	x^2	x^3	a	$-10.943417x$	$-0.4769747x^2$	$.1444317x^3$	Y_c
-8	64	-512		87.547336	-30.5263808	-73.9490304	37.7984832
-7	49	-343		76.603919	-23.3717603	-49.5400731	58.4186440
-5	25	-125		54.717085	-11.9243675	-18.0539625	79.4653134
-3	9	- 27		32.830251	- 4.2927723	- 3.8996559	79.3643812
0	0	0		0	0	0	54.7265584
10	100	1000		-109.434170	-47.6974700	+144.431700	42.0266184
+5				- 54.717085	-11.9243675	18.0539625	6.1390684

x	m_a	Y_c	(m_a-Y_c)	$(m_a-Y_c)^2$	(Y_c-M_a)	$(Y_c-M_a)^2$
-8	36.784	37.798	-1.014	1.028196	-20.835	434.097225
-7	62.032	58.419	3.613	13.053769	-0.214	0.045796
-5	72.868	79.465	-6.597	43.520409	20.832	433.972224
-3	84.772	79.364	5.408	29.246464	20.731	429.774361
0	53.276	54.727	-1.451	2.105401	-3.906	15.256836
10	42.068	42.027	0.041	0.001681	-16.603	275.659609
			Total	88.955920		1588.806051
			25Xtotals	2223.898		

Check-

$n(m_a-Y_c)^2 =$ 2223.898

$n(Y_c-M_a)^2 =$ 39720.1513

$n(m_a-M_a)^2 =$ ~~41944.0493~~

TEST OF THIRD DEGREE REGRESSION EQUATION

Nature of Variability	Within Arrays	Between Arrays
Degrees of Freedom	144	2
Sum of (deviations)^2	165248.77	2223.898
Mean Variance	1147.5609	1111.949
Log of Mean Variance Base 10	3.05977	3.04608
Log of Mean Variance Base e	7.04538	7.01386

$$z=\tfrac{1}{2}(7.04538-7.01386)=.01576$$

Conclusion:-

A third degree regression equation will suffice for the statement of the law of relationship.

DETERMINATION OF MAXIMUM POINT OF EQUATION

$$Yc=54.7265584-10.943417x-0.4769747x^2-0.1444317x^3$$

(origin at condition 10)

$$\frac{dY}{dx}= -10.943417-.9539494x+0.4332951x^2$$

Set $\frac{dY}{dx}=0$, and solve for x

$$0.4332951x^2-0.9539494x-10.943417=0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{0.9539494 \pm \sqrt{(0.9539494)^2 - [(4)(0.4332951)(-10.943417)]}}{2X0.4332951}$$

$$x = \frac{0.9539494 \pm \sqrt{0.9100195 - 18.9669160}}{0.8665902}$$

$$= \frac{0.9539494 \pm 4.4583557}{0.8665902}$$

$$= \frac{5.4123051}{0.8665902} \text{ or } \frac{-3.5044063}{0.8665902}$$

$$= 6.246 \text{ or } -4.044$$

$$X = x + 10$$

X = 16.246 or 5.956 minutes