THE HUMAN EFFECT OF MECHANIZATION

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The effect of the mechanization of industry upon the worker is a topic that has given rise to much general assertion. In so far as these general assertions are made by merely literary exponents of human situations they are often wild and fantastic. Mr. Aldous Huxley, for example, in a recent number of the *Spectator* (November 23, 1929) remarks: "The machine demands mechanical efficiency; but mechanical efficiency is practically synonymous with human imbecility." And he asks a rhetorical question as to whether "a mechanically efficient slave with atrophied powers of initiative" is "a fully alive human being." The answer to this is, of course, an emphatic negative—but the question remains as to whether this has really anything to do with the mechanization of industry. On re-reading the article, moreover, one finds that Mr. Huxley's claim that we are becoming "stupefied and aesthetically numbed" rests on a single fact of observation, the fact, namely, that he has to catch trains that are "remorselessly punctual." "It is only in an age of mechanization," he remarks indignantly, "that time can acquire such an excessive value."

But critics of established reputation and serious character are apt to make comments of a somewhat similar type, and especially if they cast a European eye over the supposedly wild proceedings of these United States. M. André Siegfried, for instance, finds himself "forced to conclude that the price America pays for her undeniable material progress is the sacrifice of one aspect of civilization."[1] The consequence of organizing production is an "atrophied individual" and an "overdisciplined community"[2]; the atrophy is due to "exhaustion that follows extremely monotonous work."[3] The view is apparently widely held that the mechanization of industry has a harmful effect upon the worker. And it must be conceded that this view is not altogether groundless; it is based, at least in part, upon fact and observation. The findings of the British Industrial Fatigue Research Board, as summarized in its *Fourth Annual Report*, are to the general effect that fatigue and monotony play a large and unsuspected part in the origin of industrial difficulties and accidents. There is validity in the assertion, therefore, as to the human effect of mechanization. But the conclusions commonly presented are too hasty and too general.

[1] *America Comes of Age*, p. 350.
[2] *Ibid.*, p. 351.
[3] *Ibid.*, p. 173.

These conclusions are not merely presented by visitors from abroad or by those exponents of the arts who still regret the alleged passing of the craftsman. Similar opinions are held by many industrialists and perhaps even by economists; and here there is less justification for the hastiness and generality. Any industrialist who maintains that work is becoming harder and less interesting, and that the appropriate remedy is to train workers to use their leisure rightly—whatever that may mean—is guilty, in even greater degree, of failure to analyze situations and of jumping to unwarrantable conclusions. For it is by no means certain yet that it is the mere mechanization that is responsible for present industrial ills. Closer analysis of particular instances is required, analysis that will tend to show what is humanly harmful—whether the mechanization itself, or the perpetuation without alteration from a former industrial régime of hours of work or other conditions. With these questions in mind, I propose to describe briefly one industrial inquiry that has been developed for rather more than two years by the Western Electric Company in its Chicago works. The course that this inquiry has run and its unexpected consequences have both a decided relevance to the general topic of this paper.

The inquiry was originally designed to discover more definite answers than are now available to certain questions as to the effect upon workers of the conditions of their work. It was suggested in the first place by the failure of a carefully arranged and carefully controlled attempt to assess the effect of illumination. The apparent implication of this latter experiment had to be repudiated not because it was repugnant to common sense but rather because the carefully established control had obviously failed to take account of the factors that were actually significant in determining the result. So when the second inquiry was begun a different form of procedure was adopted. A group of workers was segregated for observation of the effect of various changes in the conditions of work, but no attempt was made to "test for the effect of single variables." Where human beings are concerned one cannot change one condition without changing others—so much the illumination experiment had shown. So Mr. G. A. Pennock and other Western Electric officials in charge of the experiment have attempted to observe the unanticipated changes in working conditions as well as those which were due to definite design. They have attempted also to observe the consequent changes in the workers. The inquiry is still in being.

The experimental group consists of six female operators, chosen originally at random. Their work is the assembling of telephone relays—"putting together a coil, armature, contact springs and insulators in a jig and fixing the parts in position by means of four machine screws." A man

from the Piece Rates Department was selected to observe and supervise the experiment; he does not, however, act as a "gang-boss."

"Five of the girls were to do the actual assembly work, while the sixth was to stock and procure parts for each assembly operator. The nature of the test was carefully explained to these girls and they readily consented to take part in it, although they were very shy at the first conference. . . . . They were assured that the object of the test was to determine the effect of certain changes in working conditions, such as rest periods, mid-morning lunches, and shorter working hours. They were expressly cautioned to work at a comfortable pace, and under no circumstances to try to make a race out of the test."[4]

The room in which the experiment has been, and is being, conducted is a corner of a regular workroom enclosed by partitions. The equipment is "practically identical with that in the regular department" except for the addition of various devices for measuring production, for recording the temperature and humidity of the room and so on. Observers are always present whose duty it is to record any unusual happening, to be available for consultation, and to work out the results achieved by the group.

Throughout the experiment an attempt has been made to measure, or at least carefully observe, organic changes in the workers (long and short term), changes of mental attitude, and changes in production.

It is only the last series of changes—namely, those occurring in production—that lend themselves at present to exact and continuous determination. By means of a mechanical device, the officers in charge have secured a complete output record for each girl for every minute of every day of the two and one-half years of experiment. This must not be taken to imply any overpreoccupation on the part of the Company with production. The intention of the inquiry from the beginning has been the advancement of our understanding of human situations, the development of a more precise and biological knowledge of what is happening to workers in industry. As a result of this wider interest, there has been a singular freedom from the blindness consequent on trivial satisfactions.

It is true that most of the charts used to illustrate the effect of changed conditions of work are stated in terms of production. But this is done for two reasons: first, because production is quantitative and susceptible of exact determination, and second, because production is the best index of individual adaptation; that is, it shows "the combined effect of the conditions imposed."

The first records of production were taken in the regular department under ordinary working conditions for each operator (and without her

[4] Quoted from a paper by G. A. Pennock, Western Electric Company.

knowledge) during two weeks before the group was moved into the test room and constituted as an experimental unit. After this, a record of production was kept for five weeks before any other changes were introduced. In a third period, of eight weeks, the method of pay was altered; the five girls were paid by a group piece rate "which meant that each girl would earn an amount more nearly in proportion to her individual effort since she was paid with a group of five instead of a group of one hundred."

Subsequent to this, the group has worked through twelve experimental changes of working conditions. The changes introduced have been mainly rest periods of different incidence and length, with or without a mid-morning lunch. Each proposed change has been discussed with the group before it was introduced; their opinions have been given the same consideration as the opinions of those in charge of the experiment. The results have been made known to them as the records revealed them; they have been reminded, from time to time, that "racing" and special efforts are not wanted.

The effect of the various changes introduced is shown by the charts giving the production in the various periods. You will see that there has been a gradual increase in production. For some operators this increase has been as high as 35 per cent and 50 per cent of their original performance. The improvement has been surprisingly steady and seems to have been, in a sense, independent of the conditions imposed. The highest production was in period 13, during which there was a mid-morning rest period of fifteen minutes, with lunch, and a mid-afternoon rest of ten minutes. In period 11 when the operators did not work on Saturday morning the daily output increased, but the weekly output fell. But in period 12 when the girls went back to a full forty-eight hour week with no rest periods or mid-morning lunch, there was the same unexpected and continual increase. Period 13 which followed was, as remarked above, the best yet recorded; in this period the morning and afternoon rests and the lunch were restored.

This improvement was, in the language of the officials chiefly concerned, "startling"; it was also a little puzzling. The change has been too continuous and steady to be related, point for point, with the different conditions imposed. Indeed when the group is put back into the original conditions of work—forty-eight hours and no rests—the production curve during weeks ignores the change and rises steadily as before. This led the experimenters to look more carefully at the other changes observed—organic changes and changes of mental attitude.

Organic Changes. It had been agreed from the first that, in the general interest of the experiment, the operators should submit to periodic examinations by one of the Company's doctors. These examinations

CHART 1

AVERAGE WEEKLY OUTPUT
FIRST RELAY ASSEMBLY GROUP

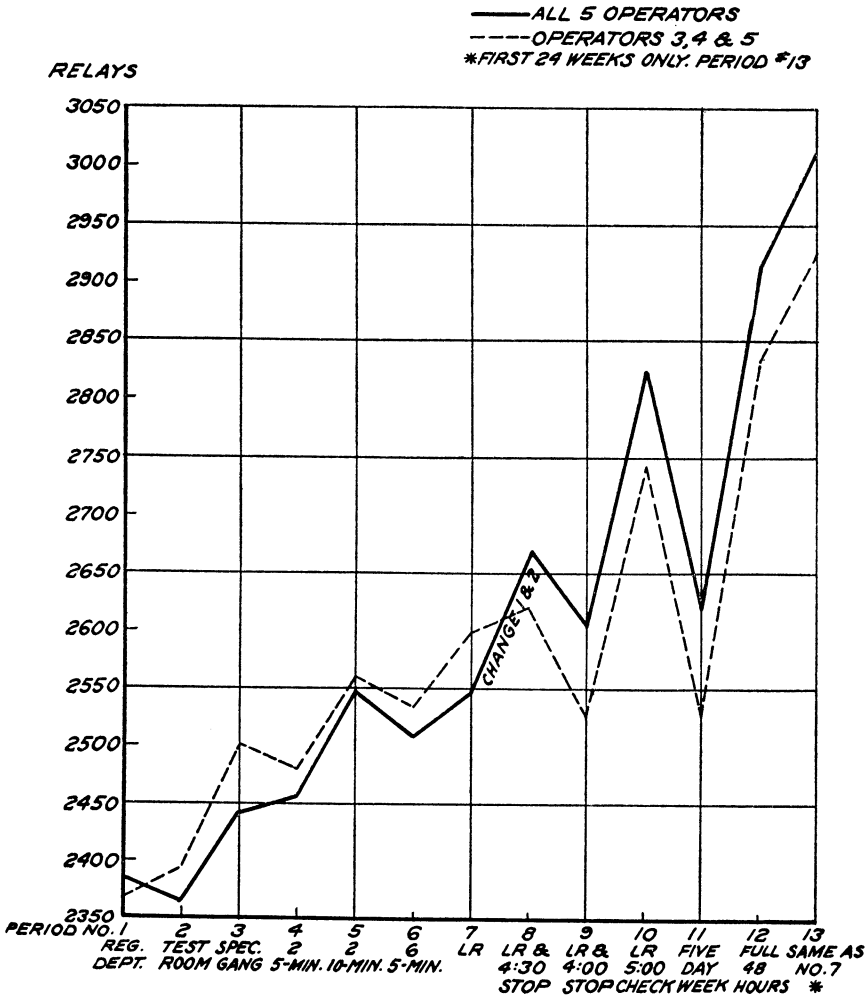
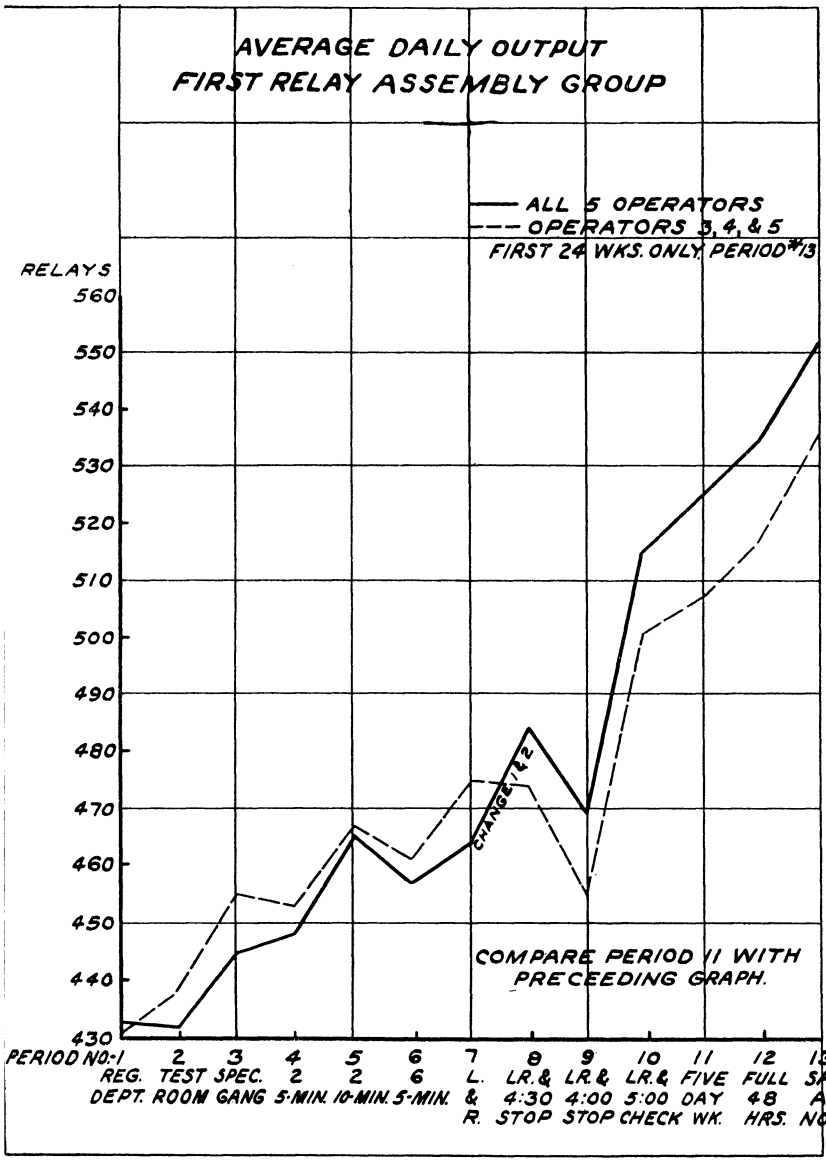


CHART 2


AVERAGE DAILY OUTPUT
FIRST RELAY ASSEMBLY GROUP
ALL 5 OPERATORS
OPERATORS 3, 4, & 5
FIRST 24 WKS. ONLY PERIOD #13
RELAYS
560
550
540
530
520
510
500
490
480
470
460
450
440
430
CHANGE 1 & 2
COMPARE PERIOD 11 WITH PRECEEDING GRAPH.
PERIOD NO: 1 2 3 4 5 6 7 8 9 10 11 12 13
REG. DEPT. TEST ROOM SPEC. GANG 2 5-MIN. 2 10-MIN. 6 5-MIN. L. & R. LR. & 4:30 STOP LR. & 4:00 STOP LR. & 5:00 CHECK FIVE DAY WK. FULL 48 HRS. SAME AS NO. 7

showed a small but distinct improvement in the general health of the group. These examinations did not, however, dispose of the general question of "fatigue."

It is difficult to discuss the question of industrial fatigue because the word is used with such a variety of meanings that, without careful definition, it is almost impossible to know the hypothesis or question involved in the discussion. There is, for example, the physiological fatigue that occurs as a consequence of heavy muscular work—"oxygen-debt," or, over a longer period, the depletion of reserves. There is another disability, sometimes described as fatigue, which is occasionally acutest before work begins. The last is obviously a mental disability—due sometimes to "monotony" or to the effect of repetitive work. The ideal method of procedure would be to record all the organic and mental changes that occur in selected workers during the working day, to relate the organic and mental changes to each other and to the situation. Since this procedure is not yet possible, or possible continuously, one has to define more precisely the tentative questions one should ask.

In the Harvard Fatigue Laboratory, certain inquiries have been made by Dr. Lawrence J. Henderson and his colleagues into the bio-chemical changes which occur in the blood stream during active muscular exercise. The following diagrams illustrate some of the differences that reveal themselves in different individuals, of normal health, in the performance of the same task. The first diagram[5] shows the effect of running at a rate of nearly six miles per hour upon the laboratory treadmill for a period of about twenty minutes. The upper shading represents increase in lactic acid content of the blood stream; the lower shows diminution of total bicarbonates or "alkali reserve." No two individuals are alike; one shows no change at all from the resting condition; at the other end of the scale several show fatigue. The most fatigued person is the youngest of the group, a boy of eighteen years; the least fatigued is a man of forty years—but he happens to be De Mar, the winner of many Marathon races. And the diagram illustrates why De Mar has been able to win his Marathons—as compared with other men, he is able to increase his exertion without disturbing his organic equilibrium. The other two diagrams—pulse rate in exercise, and skill in running—illustrate the same fact—that the best man works in a "steady state," in a condition of organic equilibrium.

The possibility of direct application to industry of investigations of this type is limited in these days, for the number of tasks demanding heavy muscular exertion is diminishing. But the indirect application is extensive and important; the hypothesis or question that we have taken

[5] Charts 3, 4, and 5 were prepared by the Harvard Fatigue Laboratory—D. B. Dill, J. H. Talbott, H. T. Edwards.

CHART 3

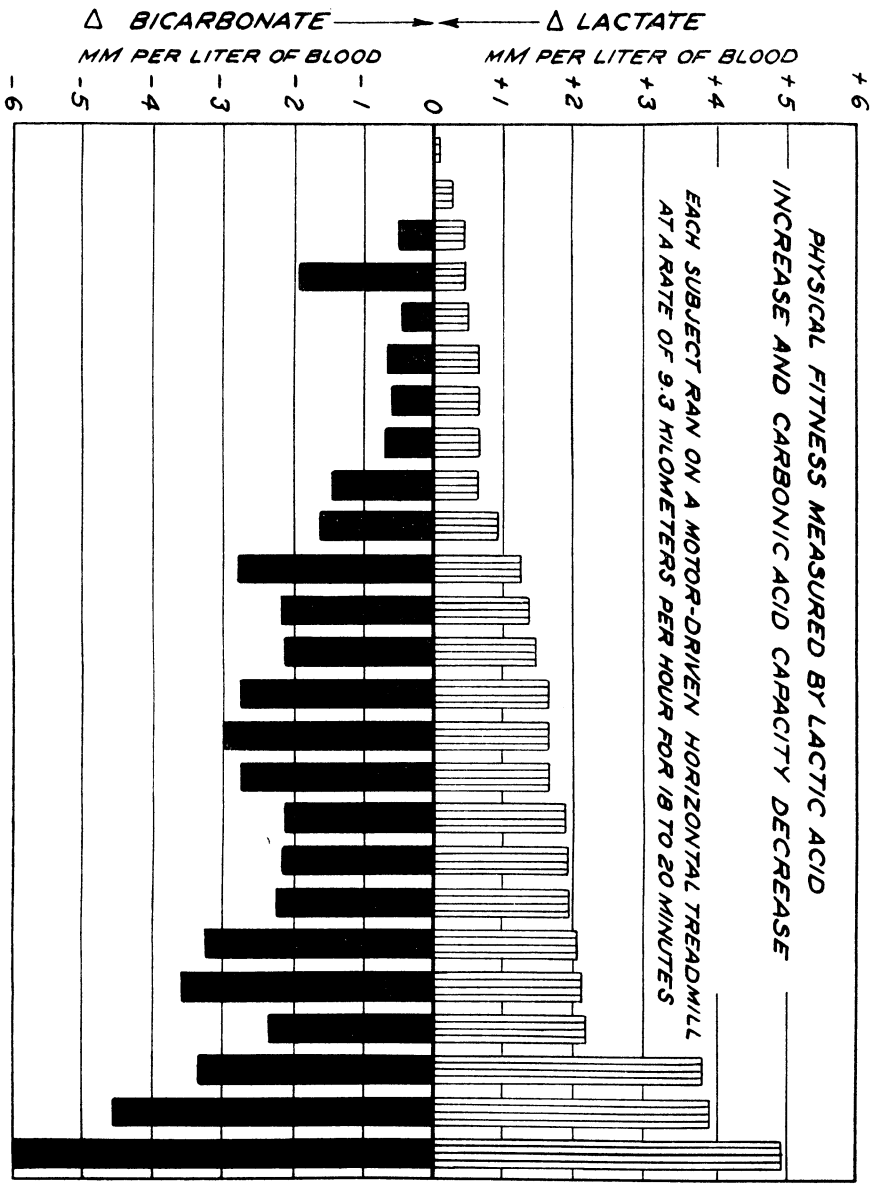
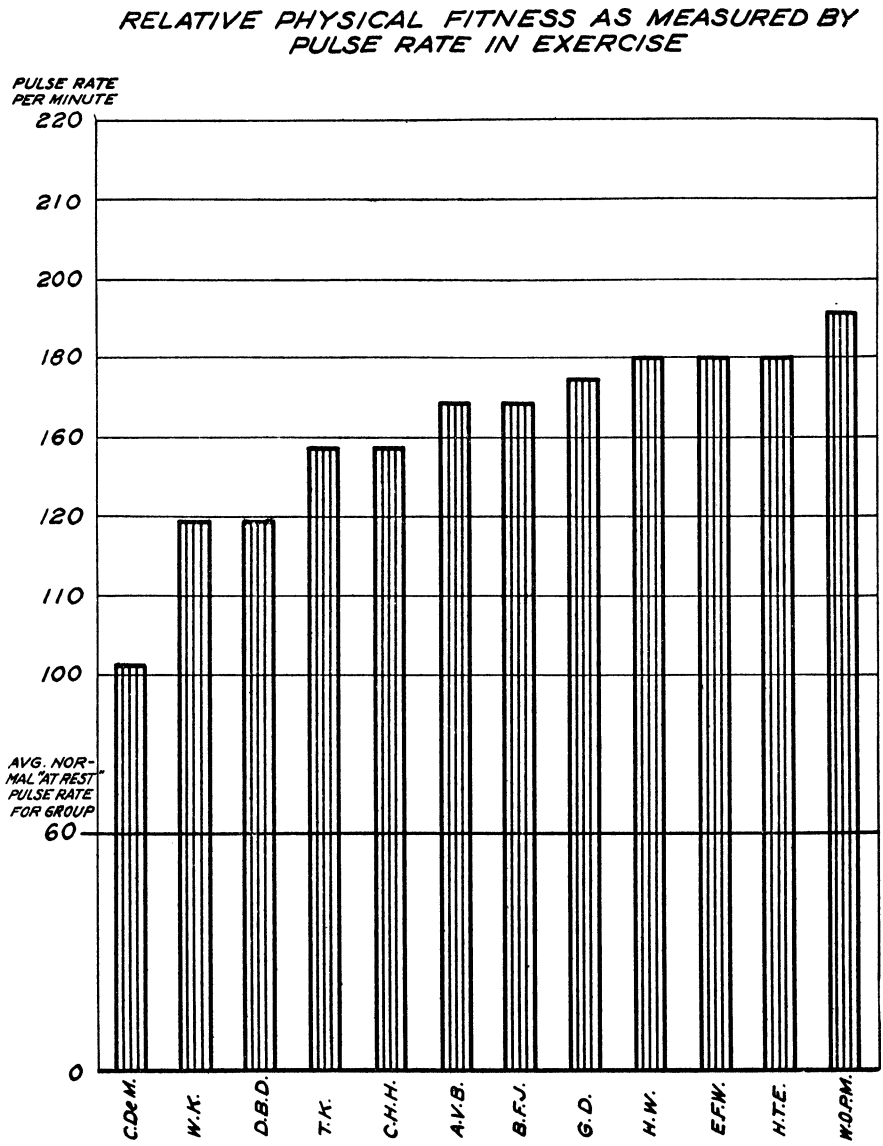
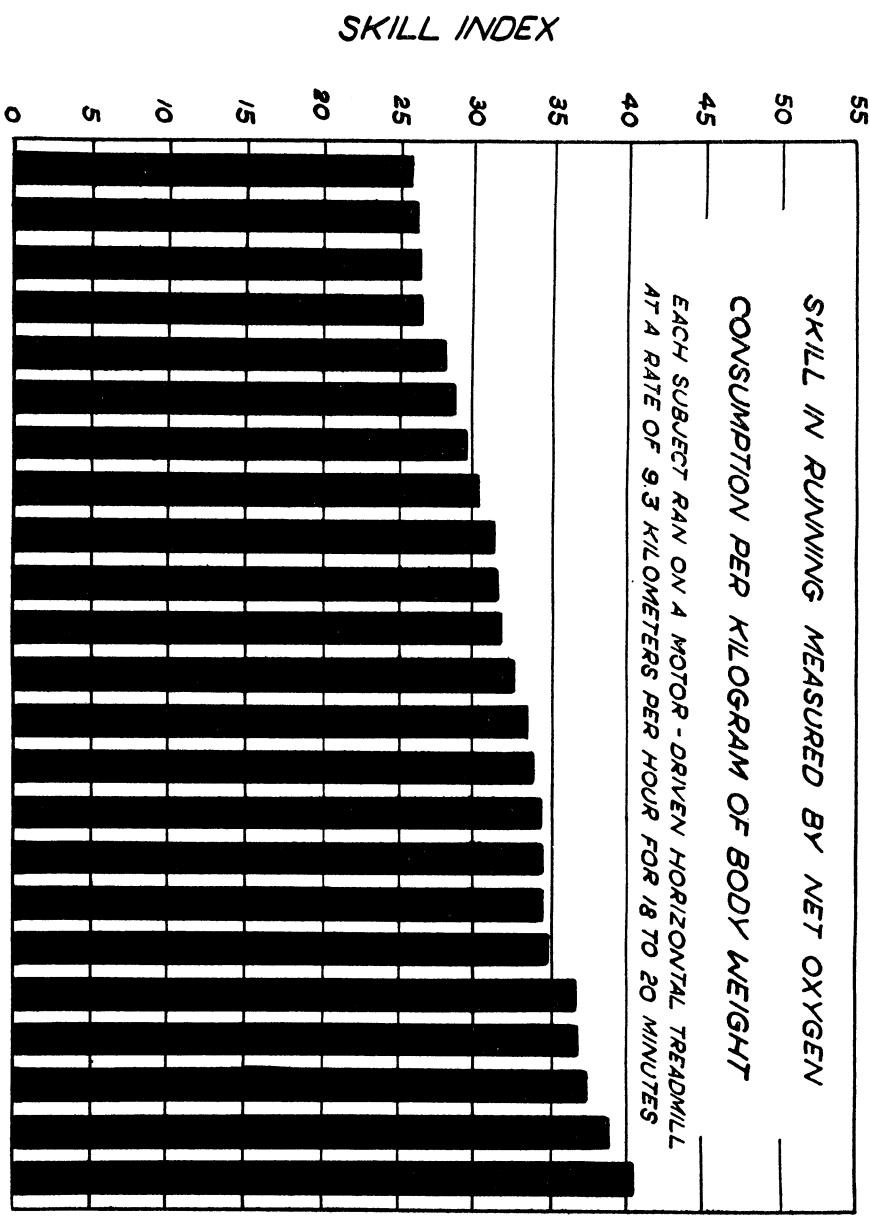

Δ BICARBONATE
MM PER LITER OF BLOOD
Δ LACTATE
MM PER LITER OF BLOOD
-6
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
+6
PHYSICAL FITNESS MEASURED BY LACTIC ACID
INCREASE AND CARBONIC ACID CAPACITY DECREASE
EACH SUBJECT RAN ON A MOTOR-DRIVEN HORIZONTAL TREADMILL
AT A RATE OF 9.3 KILOMETERS PER HOUR FOR 18 TO 20 MINUTES

CHART 4



NOTE: EACH SUBJECT RAN AT A RATE OF 5.8 MILES PER HOUR FOR 18 MINUTES, EXCEPT W.O.P.M. WHO QUIT BECAUSE OF EXHAUSTION AFTER 6 MINUTES.

CHART 5


SKILL INDEX
0
5
10
15
20
25
30
35
40
45
50
55
SKILL IN RUNNING MEASURED BY NET OXYGEN
CONSUMPTION PER KILOGRAM OF BODY WEIGHT
EACH SUBJECT RAN ON A MOTOR-DRIVEN HORIZONTAL TREADMILL
AT A RATE OF 9.3 KILOMETERS PER HOUR FOR 18 TO 20 MINUTES

from the work of our colleagues of the Fatigue Laboratory may be conveniently expressed in the form of an assertion that an individual cannot continue work, or production, unless he can simultaneously work and maintain himself in a condition of organic equilibrium. Since one finds few instances of actual "oxygen-debt" fatigue in industry, and since this is in any case no more than a particular instance of unbalance, one must look for other sources of disequilibrium, such as interference of any kind with the individual's capacity to attend what he is doing.

First, however, one needs to find a convenient indicator of changes of organic equilibrium. For some years we have experimented with "pulse product" measurements and have found that these measurements —eight to sixteen during the working day—provide a fairly satisfactory indication of organic changes. The "pulse product" shows changes in arterial tension and changes in rate of heartbeat. These changes to some extent compensate each other but both increase with muscular exertion, emotion and, in some degree, with attention. My colleague, O.S. Lovekin, has made some attempt to relate changes in pulse product to the changes measured by the Fatigue Laboratory. The two following diagrams show, first, the relation between pulse product and oxygen consumption in three experimental subjects and, second, the difference in pulse product between a trained and an untrained subject performing the same measured task. In the latter diagram you will see again, as in the laboratory experiments, that the trained subject does the same work as the untrained subject at a lower and steadier pulse product; that is to say, in a condition of superior organic equilibrium. On several occasions these measurements have been made upon the girl operators in the Western Electric test room. On every occasion the measurements showed a low and steady pulse product in these workers as compared with workers in the department outside. I show two diagrams—the one an average of the organic measurements of the test room workers; the other average measurements made on the same day of workers in a department outside. I should like in passing to point out that this approach from the physiological laboratory to industry involves a new conception of "work." In former times "work" was conceived as something that was "taken out of" the worker and wages were paid him in compensation. These measurements, in the laboratory and in industry, show that high production occurs when the worker is in a "steady state," when he is not only working but also maintaining his organic equilibrium.

Changes of Mental Attitude. These health examinations and measurements of organic condition during the working day served to assure the experimenting group that they were not "speeding up" the workers or

CHART 6

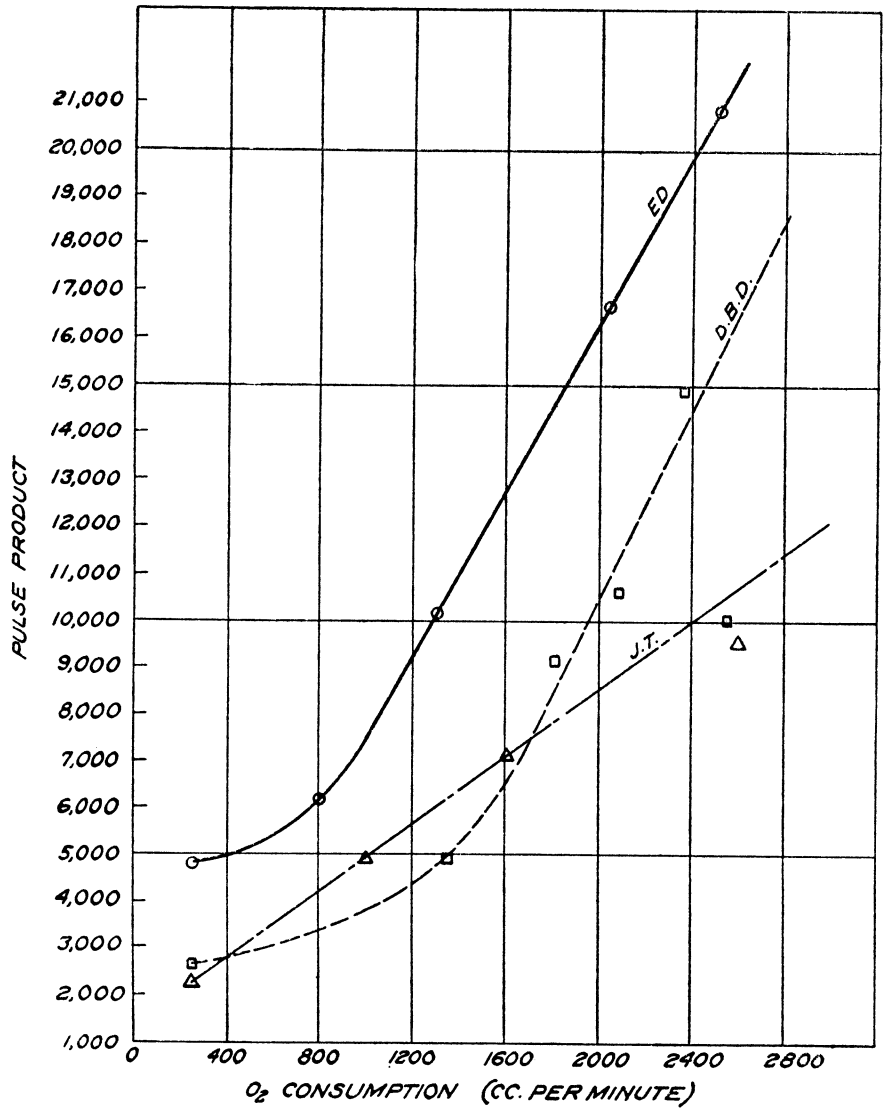

21,000
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
PULSE PRODUCT
0
400
800
1200
1600
2000
2400
2800
O2 CONSUMPTION (CC. PER MINUTE)
E.D.
D.B.D.
J.T.

CHART 7

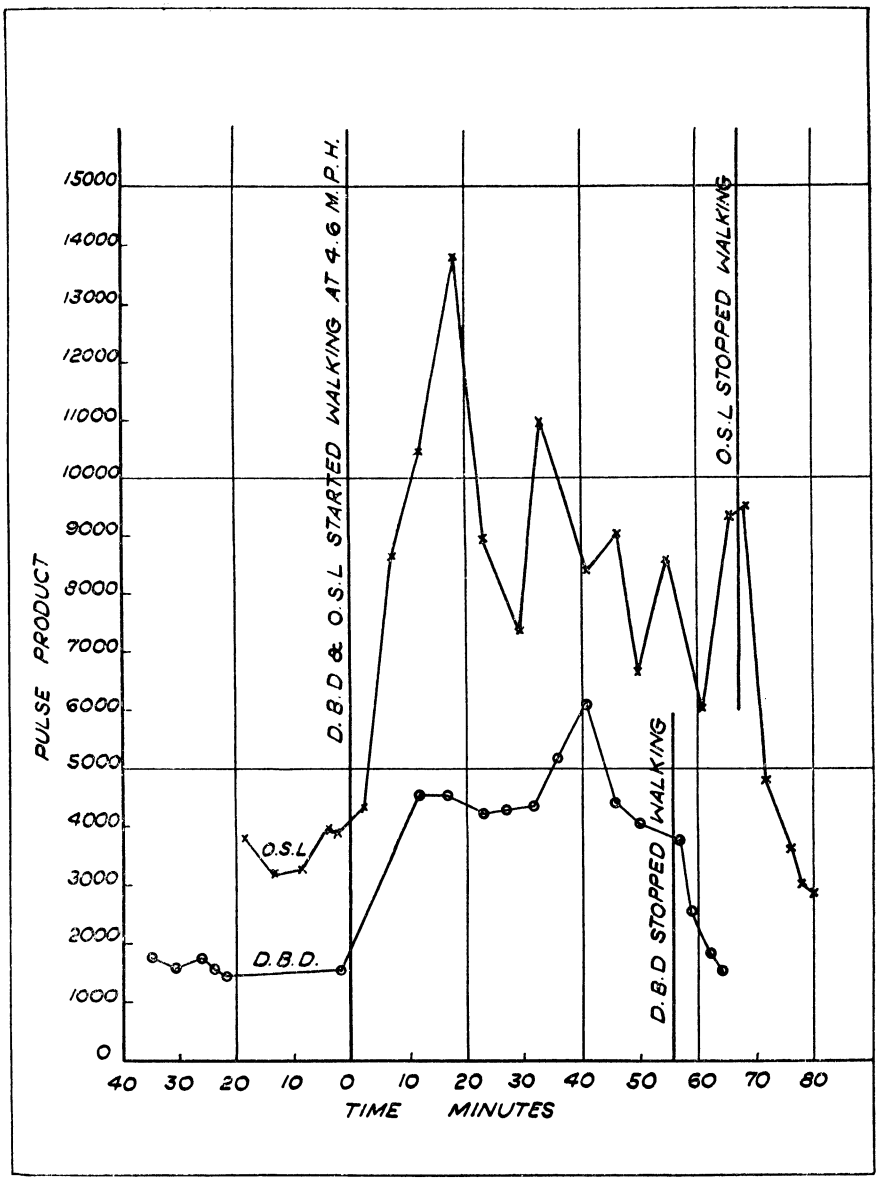

PULSE PRODUCT
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
D.B.D & O.S.L STARTED WALKING AT 4.6 M.P.H.
O.S.L STOPPED WALKING
D.B.D STOPPED WALKING
O.S.L
D.B.D.
40 30 20 10 0 10 20 30 40 50 60 70 80
TIME MINUTES

CHART 8

AVERAGES, RELAY ASSEMBLY TEST ROOM APRIL 26, 1928
FIVE OPERATORS, FIVE READINGS ON EACH POINT

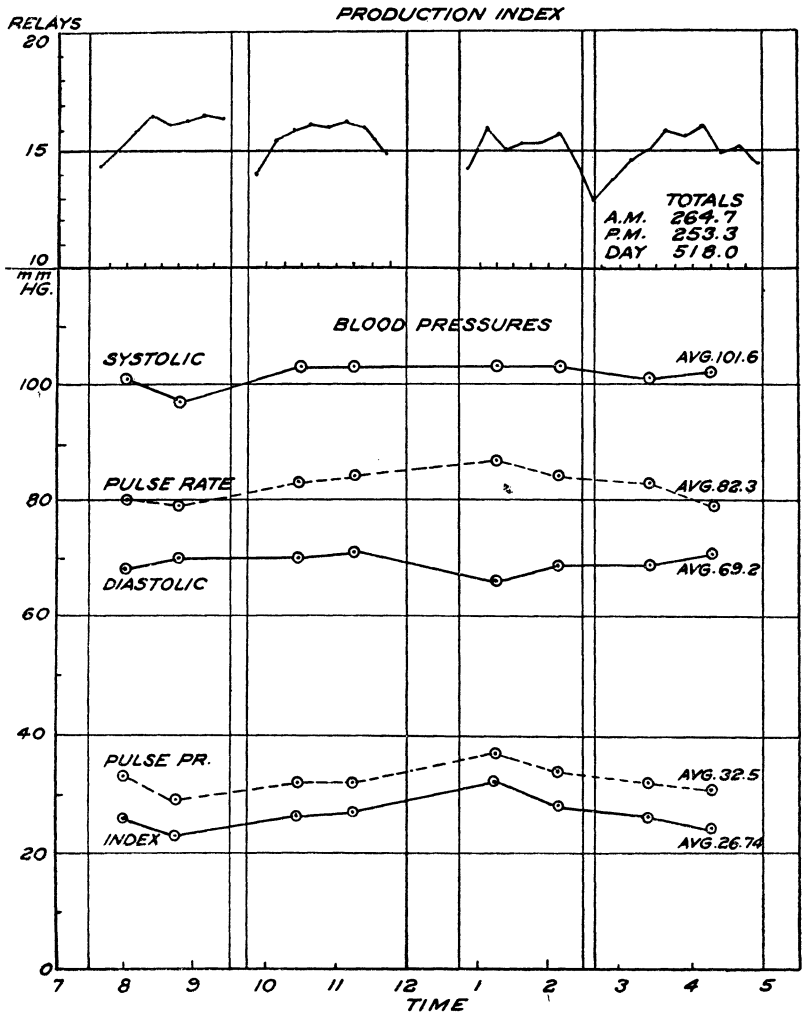
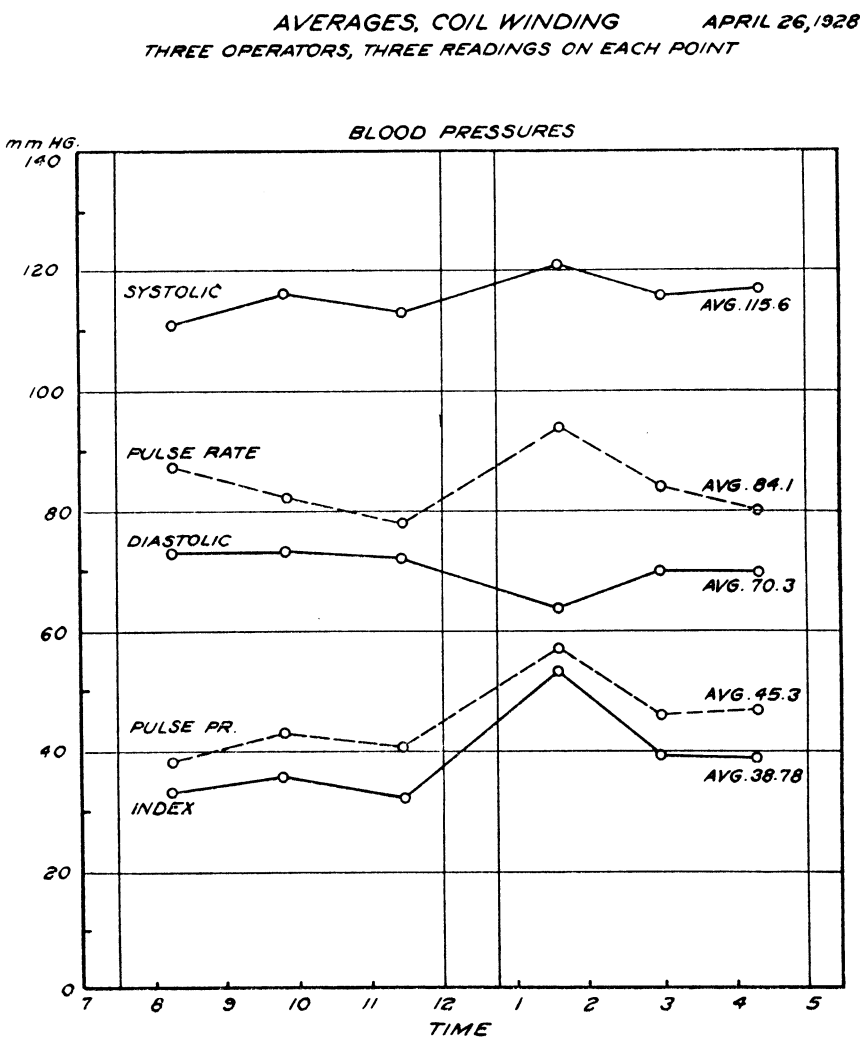


CHART 9


AVERAGES, COIL WINDING
APRIL 26, 1928
THREE OPERATORS, THREE READINGS ON EACH POINT
BLOOD PRESSURES
mm HG.
140
120
100
80
60
40
20
0
SYSTOLIC
AVG. 115.6
PULSE RATE
AVG. 84.1
DIASTOLIC
AVG. 70.3
AVG. 45.3
PULSE PR.
AVG. 38.78
INDEX
7
8
9
10
11
12
1
2
3
4
5
TIME

in any way damaging their health. But the steady improvement in production remained something of a mystery—not completely accounted for by rest-periods and improvement in working conditions. The mental attitude of the girls to their work and to their superior officers had clearly improved; it became necessary to examine and assess this improvement.

The Company officer originally put in as observer had shown himself to be particularly well adapted for the work. From the first he noted carefully, and made records of, events and changes not specified as of importance in the original routine plan. So he came to notice that one of the girls showed a much diminished record of output during two weeks of domestic crisis in her private affairs. The crisis happily over, her production mounted once more to its former level. At this time it helped her to talk the matter over with him and with her companions. The girls soon came to feel that the observer was there as a sympathetic listener and not as a gang-boss with fixed ideas about production. They talked freely every day, they lost their original shyness, and they confided to him most enlightening stories of the effect on them and others of "bully-ragging" methods of supervision. That their liking for their work increased is shown not merely by these confidences but also by their record of absences which is only a fraction of the department average or of their own former habit. So the provision of an impartial person to observe change became itself the greatest change, and has led to a complete revision of the Company's conception of supervision, and of its method of training supervisors. Whereas supervisors have generally tended to be talkers and "drivers," those who get the best results from their workers are found to be good "listeners," whose conception of improvement rests upon betterment of working conditions rather than the application of spurs or incentives to the workers. Increases of production—quantity and quality—occur in response to social and physical improvement of conditions and not as the result of conscious effort; in the majority of instances the worker, himself or herself, is as much surprised by the improvement as the observer.

The next diagram, taken from another experimental group, is a surprising instance of this. The charts show, first, the original low and irregular production of the girl known as No. 5 of the mica-splitting group; they also show her failure to improve or to keep pace with the improvement of her colleagues. The charts show, second, that after a considerable period of weeks, her production jumps to a previously unattainable high and steadies at the new level. But the charts alone do not reveal the whole story. The girl suffered an exceedingly difficult home situation. As she became accustomed to the new conditions of work she began to talk to the observer and to her fellow workers of

CHART 10

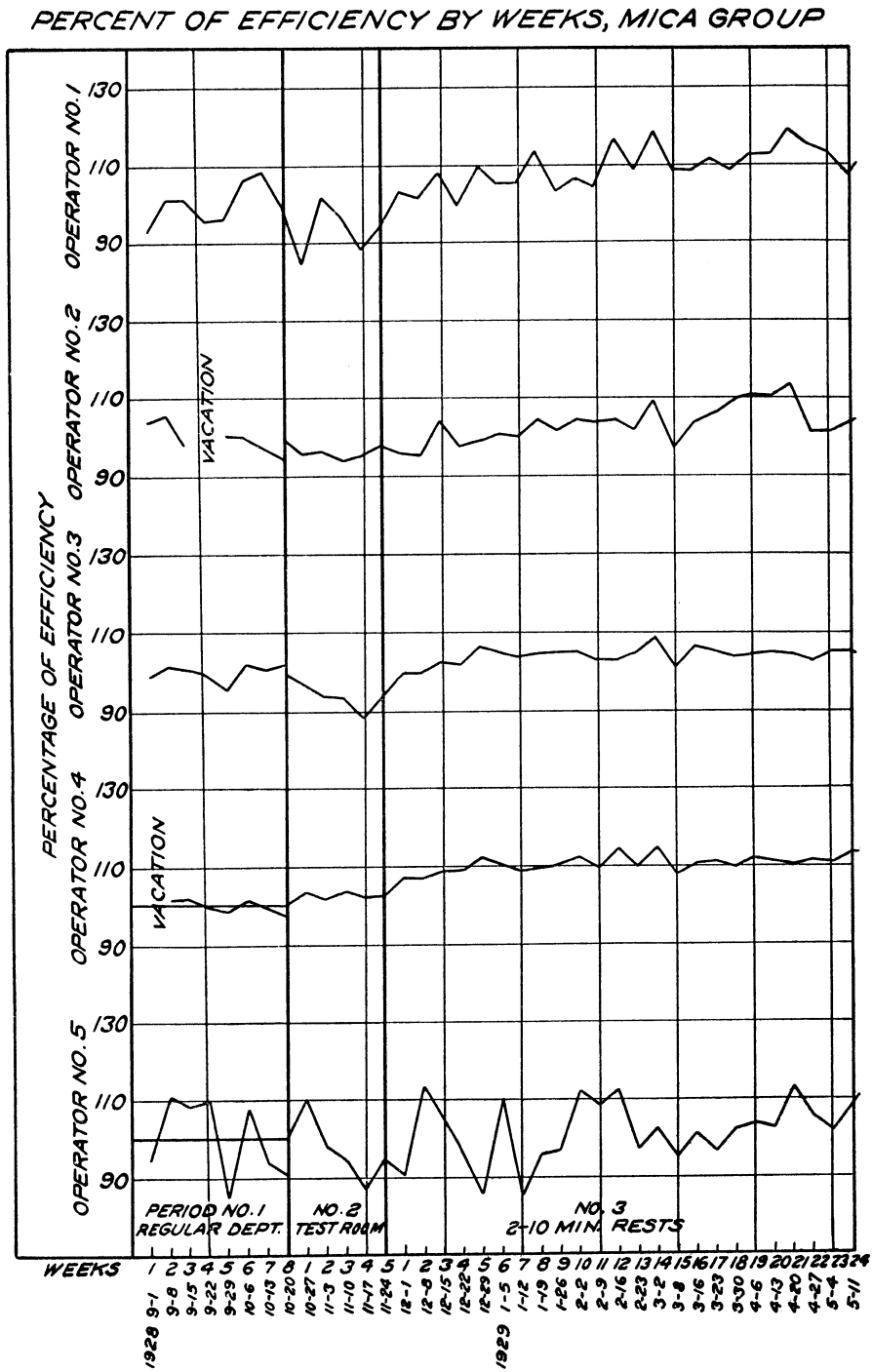
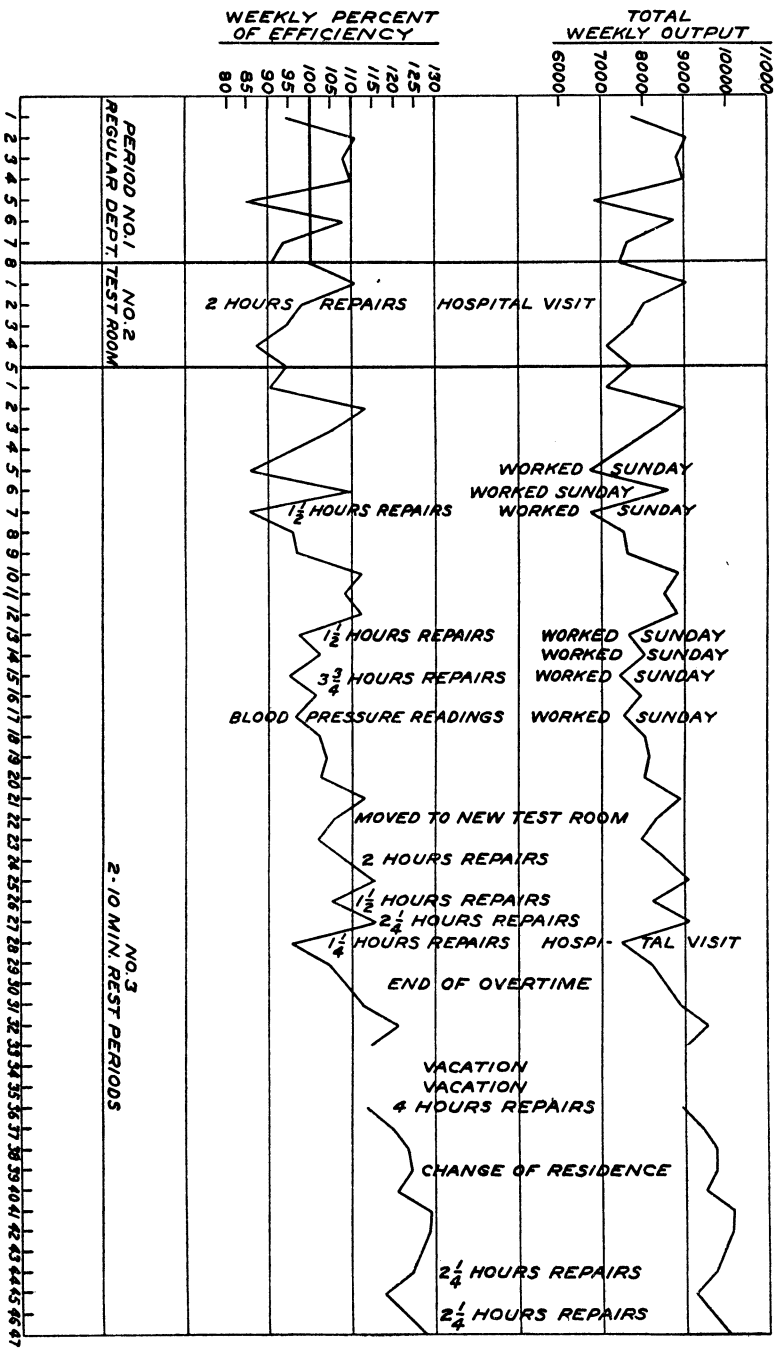

PERCENT OF EFFICIENCY BY WEEKS, MICA GROUP
PERCENTAGE OF EFFICIENCY
OPERATOR NO. 1
OPERATOR NO. 2
OPERATOR NO. 3
OPERATOR NO. 4
OPERATOR NO. 5
VACATION
VACATION
130
110
90
PERIOD NO. 1 REGULAR DEPT.
NO. 2 TEST ROOM
NO. 3 2-10 MIN. RESTS
WEEKS
1 2 3 4 5 6 7 8 1 2 3 4 5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1928 9-1 9-8 9-15 9-22 9-29 10-6 10-13 10-20 10-27 11-3 11-10 11-17 11-24 12-1 12-8 12-15 12-22 12-29
1929 1-5 1-12 1-19 1-26 2-2 2-9 2-16 2-23 3-2 3-9 3-16 3-23 3-30 4-6 4-13 4-20 4-27 5-4 5-11

CHART 11


WEEKLY PERCENT OF EFFICIENCY
80
85
90
95
100
105
110
115
120
125
130
TOTAL WEEKLY OUTPUT
6000
7000
8000
9000
10000
11000
PERIOD NO.1 REGULAR DEPT.
NO. 2 TEST ROOM
NO. 3 2-10 MIN. REST PERIODS
2 HOURS REPAIRS
HOSPITAL VISIT
WORKED SUNDAY
WORKED SUNDAY
WORKED SUNDAY
1½ HOURS REPAIRS
1½ HOURS REPAIRS
WORKED SUNDAY
WORKED SUNDAY
3¾ HOURS REPAIRS
WORKED SUNDAY
BLOOD PRESSURE READINGS
WORKED SUNDAY
MOVED TO NEW TEST ROOM
2 HOURS REPAIRS
1½ HOURS REPAIRS
2¼ HOURS REPAIRS
1¼ HOURS REPAIRS
HOSPI- TAL VISIT
END OF OVERTIME
VACATION
VACATION
4 HOURS REPAIRS
CHANGE OF RESIDENCE
2¼ HOURS REPAIRS
2¼ HOURS REPAIRS

her situation, and her preoccupations, once expressed, became less morbid and more practical. Finally, during vacation, she determines of her own accord to end the difficulty by going to live with some girl friends. She does so and at once her production rises and steadies. Production, as Mr. Pennock has said, shows very remarkably the "combined effect" of all the factors in the situation.

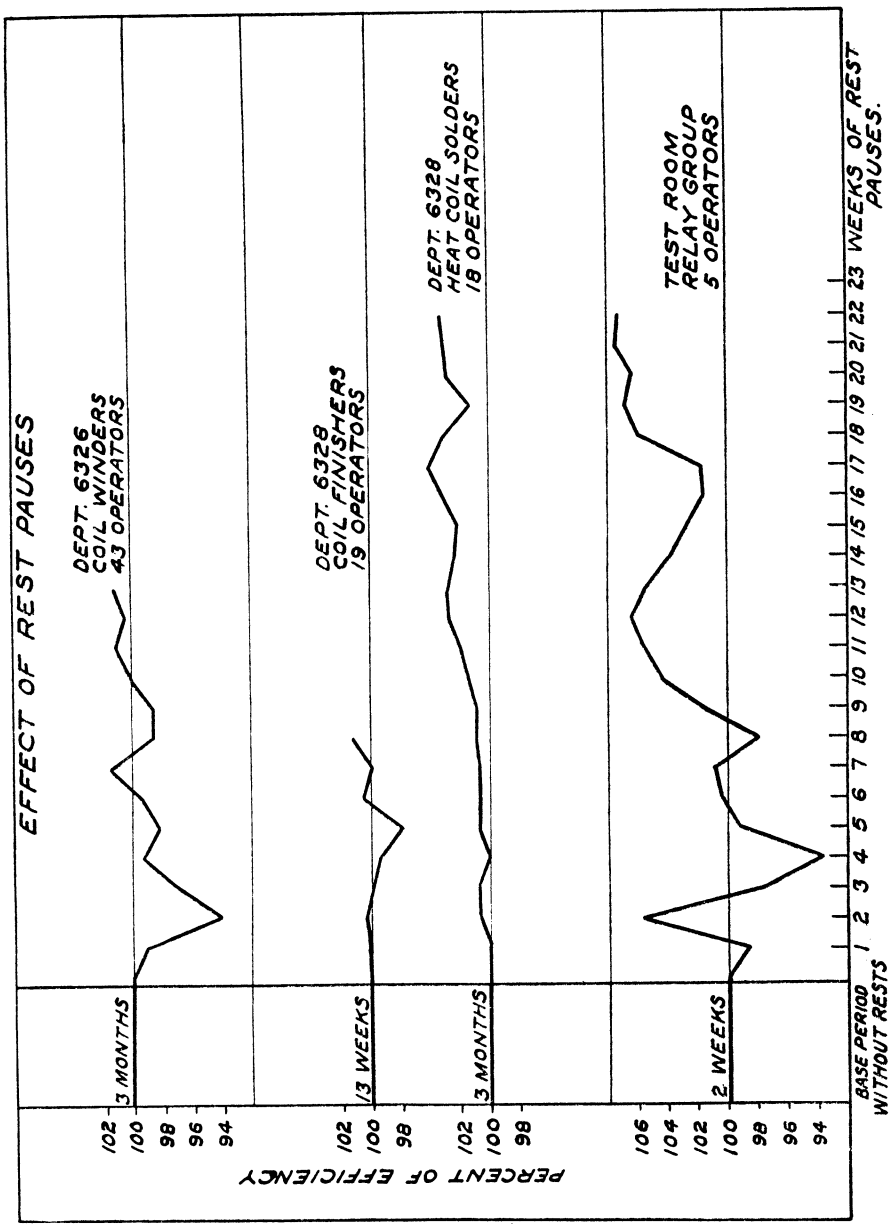
On the basis of these observations, the Company has formulated a new plan—that of "interviewing" all the forty thousand employees. This plan is already in being, and has developed as unexpectedly and as surprisingly as the original test-room experiment. The interviews are kept carefully anonymous; neither fellow-workers nor high officials can trace any comment to its source. The questionnaire method has been found to be useless; the more fruitful approach to the individual is conversational and indirect. The person interviewed can talk of any topic he chooses for as long as he likes to a trained "listener" provided by the Company; he is paid his average earnings for the time thus spent. Already over thirteen thousand workers have been thus interviewed; the effect has been an unquestioned improvement of morale in the plant and a complete revision of the Company's method of instructing supervisors.

The experiments I have reported have been made with workers engaged upon highly mechanized and repetitive operations. The tentative conclusions drawn by the Company are something as follows:

1. Total daily output is increased by rest-periods and not decreased. The rest period method has been extended to several departments, with results analogous to those of the test-room.
2. The conditions of work during the working day have more effect on production than the number of working days in the week.
3. "Outside" influences, i. e., conditions not directly relevant to the task, tend to create either a buoyant or depressed spirit which is reflected in production. A distinct relationship is apparent between the emotional status of the girls and the consistency of their output.
4. The method of the supervisor is the single most important "outside" influence. Home conditions may affect the worker and his work; a supervisor who can "listen" and not "talk" can in many instances almost completely compensate such depressing influences.
5. Pay incentives do not stimulate production if other working conditions are wrong. A second experimental group was given a pay incentive only; its production improved somewhat, but not to an extent comparable with the original group. A third group was set to work under the improved conditions, but without increased pay incentive; its improvement was, and is, entirely comparable with the original group.

The general conclusion with respect to the mechanization of industry that seems to be indicated by these inquiries is that the mechanization it-

CHART 12


EFFECT OF REST PAUSES
DEPT. 6326
COIL WINDERS
43 OPERATORS
DEPT. 6328
COIL FINISHERS
19 OPERATORS
DEPT. 6328
HEAT COIL SOLDERS
18 OPERATORS
TEST ROOM
RELAY GROUP
5 OPERATORS
PERCENT OF EFFICIENCY
3 MONTHS
13 WEEKS
3 MONTHS
2 WEEKS
BASE PERIOD
WITHOUT RESTS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 WEEKS OF REST PAUSES.

self is of no great importance in an industry that sets itself, intelligently and diligently, to discover what human changes of method must accompany the introduction of repetitive methods of work. We cannot make individuals stupid; we may make them dissatisfied, psychoneurotic, or restless. It is urgently necessary that industry should give as much attention to human as it has to material inquiry. With the institution of adequate researches, physiological, psychological, and social, society has nothing to fear from industrial mechanization.