Box 8

DR. MAYO'S REPORT TO MR. T. K. STEVENSON
ON BLOOD-PRESSURE READINGS
RELAY ASSEMBLY TEST ROOM
MAY 7, 1928

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Mr. T. K. Stevenson
Western Electric Company
195 Broadway
New York, N. Y.

My dear Mr. Stevenson:

I forward herewith for your consideration a brief report of the observations we made during our recent visit to your works at Chicago, together with certain tentative comments upon them.

You will have realized from conversations we have had on previous occasions that one of our interests is to contrive a means of ascertaining, and of measuring, the changes of organic phase that occur in an individual during his working day. Industry has at present many methods of measuring changes in productivity and output, of estimating waste of various kinds; job analysis and the planning and routine of operations are well contrived. To some extent the relation of intelligent capacity or special capacity to work is also the subject of inquiry - e.g. Mr. O'Connor's investigations at the General Electric plant in Lynn, Massachusetts. But up to the present there has been no great success in the determination of individual variations during the day nor in the relation of such changes to differences of productivity or individual satisfaction and content. Direct questioning of workers is of small use; their own analyses of their personal situations at any given time are symptomatic rather than adequate or real. We have therefore endeavored to supplement any psychological observations we have made by measuring changes in blood pressure and pulse rate. This we hope will give us not merely an objective standard by which we may determine change but also a record of differences between individuals and in the same individual which we shall ultimately be able to interpret.

I would not have you think that we are in any sense substituting physiological for psychological observations. The organism is individual and one; at one time organic fatigue may diminish capacity for work, and interest in the job will also diminish; at another time interest in the job may diminish because, for instance, of its repetitive

character, and capacity for work will then be lost to an extent that may suggest organic fatigue. It is our endeavor to find a method of determining at a given time the individual situation, without making decisions as to organic or mental "causes". This seems to us to be the first step, and the observations I submit to you herewith have been made with that end in view.

Work of all kinds involves an oxidation of body fuel - largely carbohydrate; it is the blood stream which carries oxygen to the muscular tissues in use and which carries away carbon dioxide or other "waste" products. An efficient vascular system is therefore absolutely necessary to continuous work and any index of vascular efficiency is so far an index of capacity to sustain work. It is the pumping action of the heart which maintains a sufficient "pressure" of blood against the peripheral resistance in the tissues. We can measure by means of a sphygmomanometer the maximal pressure ("systolic") of blood in the arterial system when the heart is actively forcing blood through; we can also measure the minimal pressure ("diastolic") which the arteries maintain during the rest-phase (diastole) of the heart. In addition to this we can count the number of pulsations per minute. The first three tracings which appear on the enclosed charts (excluding the productivity record at the top of the first ten charts) record the changes which occurred in the individuals named in respect of systolic (or maximal) blood pressure, of diastolic (or minimal) blood pressure and of pulse rate. The difference between the systolic and diastolic pressures is known as the "pulse pressure" or the differential pressure; this tends to increase during vigorous exertion and perhaps when work is maintained after fatigue has set in. If we multiply the pulse-pressure by the pulse-rate (number of heart beats per minute) we obtain an index figure which according to Addis (Archives of Internal Medicine 1922) and Wiggers gives a fair qualitative indication of changes in volume of blood supply. To some extent changes in blood pressure and in pulse rate compensate each other; the Addis index (or "pulse-product") is probably therefore a better indicator of changes of organic condition than either pulse-pressure or pulse-rate taken alone. The lowest two tracings on the charts are the pulse pressure and the Addis-index; in order to get this last plotted on the chart we calculated it as

$$\frac{\text{pulse pressure} \times \text{pulse rate}}{100}$$

In the physiological laboratory it is possible to make observations of other and diverse types; such observations are more

accurate and better controlled than those I report. It is not ordinarily possible in a factory to make laboratory observations (one cannot for example collect expired air and take blood samples from a worker at a machine), so we have to be content with observations of sufficient accuracy, and continuously to relate them to laboratory findings. The Fatigue Laboratory here has recently established as an observation that high production occurs when the worker is able to achieve organic equilibrium at a higher metabolic rate. That is to say, when an individual begins to work he uses more oxygen (higher metabolic rate); he can only continue to work if he establishes at this higher level of exertion an easy physiological interchange. So an organism that is thus "steady" organically is a higher producer than one that has to "stop and start"; this steadiness is, for example, characteristic of DeMar, the marathon runner. Since continuous work for a whole day is impossible, even at the relatively low level of exertion that factory operations demand, a system of "breaks" or intervals for rest must be deemed successful when it enables the majority of workers to work at a "steady" organic equilibrium. This is achieved mainly by excluding from the day's work those moments of very high activity which occur when there are no rest periods. In looking over our records, therefore, we look for

(a) a relatively low index - moments of great exertion excluded
(b) a "steady" index figure.

Turning to the ten records we obtained of the five workers in the test room at Chicago on April 25 and 26, I find that upon the whole these two requirements are fulfilled.

(1) [redacted] - April 25.
The index is somewhat irregular, although her production is high. On this day she ate enormously which may have contributed something to the irregularity. There is a question as to her heart action in the medical examination.

April 26.
On the second day the production of all the girls was lower. This was perhaps due in part to our interruptions - we do not usually take these records on successive days. She is still within the index figure one gets in girls who work without rests.

(2) [redacted] - April 25
teady index. The highest production for the two days of our observation.

April 26.
Again a low and steady index after the morning adjustment. The highest producer for the day.

(3) [redacted] - April 25 and 26.
have been a low and steady index but for the fact that on both days she apparently "knocked off" work, more or less, in the first afternoon period. I interpret thus because the systolic pressure falls, the diastolic rises, and the pulse rate for a time falls. The productivity curve confirms this. I am sure she is not aware of her change of organic condition; it may be due to digestion or to an afternoon fatigue.

(4) [redacted] - April 25 and 26.
w and steady index both days. Production better than workers outside the test room though not equal to the best workers (Nos. 1 and 2) within it.

(5) [redacted] - April 25 and 26.
a low and steady index. There is a possibility here of a fatigue in the middle afternoon.

The two charts that give the general averages for the two days (five operators, five readings per point) are interesting. These charts dispose of moments of individual nervousness or excitement at our methods and approach. (That the girls are thus excitable is shown by the first measurement we took of [redacted] on Tuesday, April 24. At that time her blood pressures were 130 Systolic, 84 Diastolic, Pulse rate 120: These measurements are similar to those that the doctor obtained during examination and would be too high, if accurate. When accustomed to us, she gave an approximate reading of 110-80 blood pressures and below 90 for pulse rate.) Individual variations of no significance thus disposed of, the average index is very low, comparatively speaking, it is steady and is associated with high production.

As a further control of our observations, we took measurements on the second day, April 26, of three girls working in the coil winding department, without rest periods.

[redacted].

The index is irregular and much too high. The afternoon is

certainly fatigue and looks like organic disaster. It would be wise to have this girl medically examined. She seems to be a good sort and a hard worker - heavy outside or home responsibilities and conscientious.

[redacted] and [redacted].
Index irregular and high. Both these girls are probably "knocking off" work in the afternoon without knowing it and so saving themselves.

These three workers were chosen because they sat at the end of a row and were easy to get at with a sphygmomanometor. Owing to the difference between [redacted]'s curve of high exertion or fatigue and the other two curves, the last two afternoon measurements do not average fairly. The points to observe are the high systolic average 115 (101 both days in the test room) and the high index 38 (25 and 26 in the test room). This means greater exertion, more fatigue and the attendant industrial and mental ills.

Up to this point I have said little of the relation of organic equilibrium and productivity to mental preoccupations of a pessimistic or paranoid order. We have always found that there is such a relation (the "causes", as I have said, may be in either field, or both at once). We found an interesting illustration of this in your records at Chicago. A former worker in the test room, Irene, was permitted to withdraw because she complained of fatigue, became paranoid and "turned Bolshevik." In looking up her medical record we found that her blood analysis showed

(a) Haemoglobin 68% (the others all over 80%)
(b) Red cells under four million (the others over four and a half)

These figures are so low that the girls might be said to have a secondary anaemia. She should have medical examination and advice. My interest here is that the others have become less suspicious and have improved in health; [redacted] had to drop out because of the preoccupations she developed under the test.

Finally, I have included a diagram which will enable you to compare the (organic) conditions in your test room with conditions we have found elsewhere. The measurements are made on men at the American Pulley Company (No. 2) and the Continental Mills (No. 4 - the order is wrong in the diagram, Nos. 3 and 4 are misplaced); the other measurements are all of girls. In the laboratory it has been decided that the most abnormal position for a human is continuous standing still; it is interesting to observe that the job which shows up as worst in this list (No. 1) is one which involves hours of continuous standing with little movement -

the two rest periods are not enough. The men at the [redacted] working for ten hours a day with four ten-minute rest periods and a lunch interval of 45 minutes show a better index than the coil-winding girls of your Company who are seated. The girls in your test room show a better index and a better diurnal variation than we have known elsewhere. The fact that you have obtained this with increased production better health and an improved mental attitude should make the experiment which you and Mr. Fennock have conducted of high value to industry.

I understand that in the near future you intend to abolish the rest periods and the morning lunch in the test room. I should like to have [redacted] and [redacted] go out to Chicago at some time convenient to you after this change to repeat the observations we have made. Repetition of these measurements under the changed conditions cannot fail to reveal some significant differences and may help us greatly to interpret our findings. It is usually wise in such cases to have the subsequent observations made, if possible, by the same persons - especially when measurements may be affected, in one way or other, by small differences of situation.

I should like to thank you for the opportunity we have had of participation in a most inter sting experiment. Mr. [redacted] received us with the utmost courtesy; so also did Mr. C. [redacted] and Mr. [redacted]. Our stay was made most pleasant and interesting by reason of Mr. Fennock's hospitality; I discussed many questions of "industrial relations" policy and learned much.

I enclose herewith a statement of our expenses, as requested by you. I regret that the cost was high - but we work more efficiently as three than as two or one.

On behalf of myself and my colleagues of this department I should like to express once again my gratitude for your courtesy and hospitality.

Yours very sincerely

Enc.
EM?CB [redacted]