THE STUDY OF FATIGUE

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Industrial fatigue is hard to measure. The typical laboratory tests fail to record a worker's real efficiency and recourse must be had to an analysis of curves of actual output, obtained under varying but carefully observed conditions. Thus, experiments on the introduction of twenty-minute rest pauses in a boot factory showed an average increased output of 44 per cent. These and other recent investigations of the Industrial Fatigue Research Board, as well as of the National Institute of Industrial Psychology, are admirably summarized and weighed by the author, who brings to his task a medical background as well as a rich experience of research in both the laboratory and the shop.

In approaching the subject of industrial fatigue, it will be well first to summarise our knowledge of fatigue as derived from laboratory experiments.

THE NATURE OF FATIGUE

The muscle-nerve preparation served as the first instrument for inquiry into muscular fatigue. It has provided us with data which strongly suggest that each striated muscle fibre when stimulated responds by an all-or-none contraction; that is to say, if the stimulus is but sufficiently strong to produce a contraction, the muscle fibre contracts to the same extent, however strong be the stimulus. We have reason to believe that the muscle fibres while at rest secrete within them a store of material, in the form of glycogen, ready to break down, on or after the application of a suitable stimulus, into lactic acid, carbon dioxide, etc., a decomposition which is associated with contraction, the generation of heat and the production of electrical changes. It is conjectured that different muscle fibres within any one muscle show different degrees of irritability, so that while a weak stimulus is only able to affect a few muscle fibres, a strong stimulus will involve a larger number of fibres, the degree of contraction of the whole muscle thus being determined by the number of muscle-fibres which are at that moment in a state of contraction.

Study of the muscle-nerve preparation has further taught us that the response of the muscle-fibre is not

[1] Parts of this paper were delivered as a lecture to the Summer School of Columbia University, New York, in August, 1924.

only determined by the amount of stored material available but also by the rate of removal of the products of decomposition of that material. To these two factors—loss of explosive material and accumulation of its katabolic products—have been generally attributed the phenomena of muscular fatigue, i.e., the loss of response to stimulation consequent on repeated muscular exercise.

The muscle-nerve preparation also indicated that the end plate—the structure in which the nerve-fibre terminates at the muscle-fibre—is more readily fatigued than the muscle-fibre itself, blocking the transmission of the impulse from nerve to muscle at a time when the muscle-fibre is still responsive to a stimulus applied to it directly.

The importance of inhibition

Then came experiments on the intact organism by means of the ergograph, an instrument ideally recording the voluntary contractions of a single muscle—a series of flexor movements at a single knuckle joint, involving the lift of usually a relatively heavy weight. In these conditions fatigue appeared to be largely due to inhibitory nervous impulses ascending from the muscle to the central nervous system, and making it more and more difficult for impulses to descend to that muscle which would otherwise throw it into contraction. Some of these ascending impulses from the exercised muscle effect consciousness in the form of discomfort, pain or cramp, but others act purely reflexly, blocking the path of outgoing impulses, thus inhibiting voluntary movement. Hence when volition is powerless to evoke further ergographic records, they may still be obtained by stimuli applied on the skin surface to the motor nerve running within the limb to supply the muscle whose contraction is being studied.

The importance of nervous inhibition in safeguarding our striated muscular system from exhaustion is also seen in certain conditions of general fatigue or in certain stages of the influence of alcohol. The higher nervous levels appear normally to exercise an inhibitory influence over the lower, which may disappear in fatigue and under the influence of alcohol. Such loss of higher control may manifest itself temporarily in an increase in the amount of muscular work performed. Hence higher fatigue does not necessarily imply immediate reduction of muscular work, although it involves all the consequences of lessened control—first, loss of that delicate coördination of movement associated with the higher nervous levels, and second, extravagant expenditure of muscular energy.

Ergographic and muscle-nerve experiments also indicated the importance of rest pauses in relation to recovery from the effects of muscular exercise, a far greater total amount of work being elicitable when more frequent rests were introduced.

The work curve

Next came laboratory experiments into mental fatigue, which consisted essentially in the study of curves of output recorded minute by minute, or five minutes by five minutes, during an hour or more's mental work. This work was of a simple uniform character, e.g. adding pairs of figures, or erasing a prescribed letter throughout a printed text. Here, again, the value of rest pauses on subsequent output was demonstrated, and attempts were made to determine the most favorable length of rest pause for a given period of mental work. But the chief value of such experiments lay in the analysis of the work curve, which brought to light the play not only of practice and fatigue, not only, that is to say, of the acquisition of skill and of the loss of efficiency produced by exercise, but of (*a*) incitement, the warming up of the subject to his work after he had been withdrawn from it, (*b*) settlement, the neglect of distracting conditions—and (*c*) spurts, of which the most striking are the initial spurt when the subject starts fresh to his work, and the end spurt when he realizes that the end of his work is approaching.

FACTORY FATIGUE

Valuable as have been the results of these laboratory experiments, they have proved far from adequate in their practical application. The conditions of laboratory experimentation are widely removed from those of work-a-day life. Muscular fatigue cannot be isolated in the factory, as in the laboratory, from such influences as skill and intelligence which depend on the proper functioning of the highest levels of the central nervous system. The most unskilled labour is really skilled, in the sense that there are good and bad methods of carrying it out. Further, a worker's movements cannot be compared with the movements of the subject of an ergographic experiment who lifts his finger repeatedly and rhythmically with the utmost force and to its utmost extent until he can move it no longer. The worker knows better than to exhaust himself in a relatively brief period by employing his utmost energy; he regulates his output according to his feelings of fatigue and according to the length of the period over which he has to work.

Variations of output

Thus it comes about that, whereas in laboratory research feelings of fatigue are not incompatible with a temporarily increased output of work, owing to the removal of normal inhibitory influence, in everyday life, as Muscio's experiments[2] have indicated, such feelings are more closely related to the varying output throughout the day. Moreover, as he has also shown,[3] even when no work has been done, a worker's efficiency, as demonstrated by interpolated tests, varies at different hours, the efficiency curve in a resting worker being similar in form to that revealed by actual work throughout the day but at a higher level.

Adaptations to length of day

The adaptation of the worker to the length of the working day has

[2] Brit. Jour. Psychol., 1921, vol. xii, pt. 2, pp. 150–162.

[3] Ibid., 1920, vol. x, pt. 4, pp. 327–344.

been well demonstrated by Vernon[4] in his observations on the effects of changes in the length of the working hours. An improvement in rate of output almost invariably results from shortening the working day; but generally it does not occur immediately, or at all events it does not attain its maximal effect immediately. Weeks or even months may elapse before the full beneficial effect of the reduction of hours on rate of output is reached. The output continues slowly to rise for a period varying, apparently, with the kind of work involved, and varying no doubt with the worker, until uniformity is again established. This can hardly bear any other interpretation than that the worker consciously or unconsciously adapts himself to the length of his day's work or of his work spell or shift. Hence, when that length is suddenly shortened, some considerable time is needed, during which he changes his rate of output, before he can adapt himself completely to the new conditions of work.

There is no doubt a complexity of other factors determining this change in rate of output. Thus, the worker's output is consciously or unconsciously influenced by that of his fellows and by the tradition of the factory. For this reason, the speed and extent of improvement in rate of output in a shop must depend on those who initiate it. By force of suggestion if they are workers who have prestige among their fellows their action will be more or less unconsciously imitated, whereas workers of inferior standing will arouse resistance rather than coöperation. But, apart from such complicating factors, the broad conclusion we are justified in reaching is that more or less unconsciously the industrial worker regulates his rate of output, according to the length of his working spell or day.

In this connection, it is interesting to observe that whereas adaptation to shortened periods of work is slow, adaptation to lengthened periods is quick. Thus, in the case of mill men engaged in the tinplate industry, while it took eight to ten weeks to reach the maximum of output after a change from an eight-hour to a six-hour shift; on reversion to the eight-hour shift the output fell at once approximately to its previous level without any appreciable period of adaptation.

But apart from the fact that the worker does not, like the ergographic experimenter, continually put forth his utmost power, he differs further in the fact that he is not always using the same joint or the same muscle. He varies his posture as he begins to feel discomfort, now using one set of muscles, now using another, for the same work, so that the previously used set may regain their freshness. Moreover, he is not contracting his muscles against so heavy a weight that in a relatively small number of lifts it is likely to produce complete impotence to execute further contractions.

Monotonous work

Similar objections hold in the case of laboratory experiments in mental

[4] Indust. Fatigue Res. Board, Report No. 6.

work, where, again, the subject is working his very hardest for a relatively short period of time, and the work performed is of the most uniform monotonous character, so uniform, indeed, that after a little practice, it is at times carried on quite unconsciously. If monotonous work in industry can be called—as I think it should be called—mental work, then the laboratory experiments are to that extent comparable with the monotonous conditions of industrial life. But they are clearly incapable of throwing much light on fatigue in work which demands the continual conscious exercise of intelligence.

ADAPTATION

This brings me to a further difficulty, depending not on the inapplicability of laboratory experiments to industrial conditions, but on the incompleteness of our knowledge of fatigue derived from experiment itself. It is impossible to believe that in such experiments as I have described we have the whole story of fatigue.

No doubt, in ergographic and in heavy muscular industrial work, pain or discomfort are largely instrumental in inhibiting further activity. But these are protective only. If they be disregarded, or if such feelings become blunted, further activity is possible. Moreover, increased interest, excitement, the influence of emotion or suggestion, may, as is well known, either prevent fatigue from manifesting itself or lead to a revival of muscular or mental activity. Let us endeavor to form some idea of how this occurs.

Muscular contractions, and acts of apprehension, decision and the like are one thing. They may perhaps be regarded as explosive acts fired off much as a heat spot fires off, so to speak, its sensation, and then requires rest for recovery. But these contractions and acts occur in a setting of tone, posture, and attitude, perhaps much as the heat and cold sensations appear to occur in a setting of sensibility to warmth and coolness. The muscular contractions and mental acts are of an intenser, more momentary character, readily susceptible of fatigue, whereas muscular tone and posture, and mental attitudes are of a milder, more prolonged character, far more resistant to fatigue.

Sources of fatigue in mental work

We can endure the light of a northern summer for hours without fatigue: adaptation appears to enter in its stead. We can maintain a given posture likewise for a prolonged period: adaptation appears to step in, coördinating activity within pairs of antagonistic muscles, and perhaps setting up some "give and take" between them. It is this process of adaptation which finally tires. In mental work it is the ability to preserve the right attitude that finally tires, then making further mental work disorderly and useless. Of this kind of fatigue we know practically nothing. When we are engaged on a given piece of mental work—let us include even the repeated addition of pairs of figures and muscular work, for even this, I would insist, involves mental work—all conflicting nervous impulses must be inhibited, other distracting ideas and other muscular movements must be suppressed in so far as they are incompatible with the work at hand. Such inhibition in itself involves work. I know of no physiological evidence to support McDougall's view that inhibition is merely the result of the drainage of energy into other channels which are simultaneously active. The suppression of conflicting emotional states in psycho-neurotic conditions affords an adequate example of how active a process inhibition is. But this inhibition of incompatible attitudes though it may last a long time, cannot continue for ever. It becomes more difficult, partly perhaps through nervous blocking, partly because the inhibited or repressed attitudes and acts gain in strength and finally insist on manifesting themselves by bursting through the restraint imposed upon them.

Boredom and fatigue

We thus gain some idea of the place of boredom in our conception of fatigue. An attitude may be maintained, at first, by interest, the work being intrinsically and spontaneously attractive. Later, volitional acts have to be employed to maintain this attitude, and as these become more difficult and more ineffective, the feeling of interest gives place to one of increasing boredom.

It is naturally the most delicate and latest acquired functions that suffer most in mental fatigue. In the work of adding pairs of figures, it is not so much the speed or accuracy of the reaction to 2 + 1 that becomes impaired as the ability to attend to and to apprehend the meaning of this presentation. Reaction times are in themselves poor indices of fatigue. What suffers is the inability to preserve the proper attitude.

The more intelligent the worker the more irksome becomes monotonous work, the more difficult becomes the maintenance of the required attitude, because of the demands of his intellectual processes. An interesting illustration of this is afforded by a recent investigation by Miss I. Burnett[5] who in a laboratory experiment engaged four unemployed work girls in the daily repetitive work of cross-stitching throughout two months. Of these four girls, two had been rated by an intelligence test as highly intelligent, the third showed average intelligence and the fourth was distinctly below average in intelligence. Each of the first two girls showed distinct signs of boredom in the work; the one was restless and yawned, seizing every opportunity for change of posture and engaging far more often than the others in conversation, while the other confessed that she found the work "very tedious and would not like to do it regularly." These two most intelligent girls "were capable of reaching a high output from time to time but were unable to maintain it." The worker who was rated third in intelligence did by far the best work, 12 and 16 per cent respectively more than the two girls who were rated highest in intelligence. She declared at the end of the experiment that "so far from

[5] Jour. Nat. Inst. Indust. Psychol., 1924, vol. ii, no. 1, pp. 18–23.

experiencing any strain of monotony as a result of the repetitive work, she had rather liked it." Her regularity of output, too, was far greater than that of any of the other girls, 14 and 25 per cent greater than the two most intelligent, and 22 per cent greater than the least intelligent. The latter showed very considerable improvement with practice but made a very bad start and appeared hampered by clumsiness, holding the needle with difficulty, and picking it up with difficulty from the floor on to which she frequently dropped it. She offered no objection to the repetitive work, but complained of the occasional conversation of the other girls.

The practical outcome of these experiments is that monotonous work requires a certain degree of intelligence, but that it suffers appreciably if too great intelligence be brought to bear on it. Such ill effects may be safeguarded, as we shall see, by rest pauses and by changes of work. They may also be prevented by recourse to day-dreaming and in certain circumstances, especially when the work is rhythmical, by refuge in song.

Effects of varying work

In some laboratory experiments on the effects of varying work, carried out by Wyatt[6] on three young adults during two daily spells of 2½ hours each, lasting over six weeks, the output increased by amounts varying from 2.4 to 24.2 per cent. The errors decreased by amounts varying from 9.2 to 55.1 per cent (according to the subject and the work), when the nature of the work was changed at about fifty-minute intervals. The work was of three kinds—adding in the head sets of 5 digits, adding, by means of a comptometer, columns of 10 digits, and pulling every half-minute against a powerful spring balance with the right and left hands alternately. During three of every four days one or other of the three tests was worked continuously. On the fourth day each spell was divided into three periods of fifty minutes, and the three tests were consecutively given during the three periods. The results, as I have said, varied according to the worker and his liking for the work performed.

On the other hand, too many changes of work must obviously have a deleterious effect on output. In a manufacturing chemist's work, an increase of from 17 to 20 per cent in wages earned was found by Wyatt[7] to occur when the operative changed approximately every half-hour from one process to another instead of, as before, carrying out from 100 to 250 different changes of process in the course of the day, giving an average duration of from two to five minutes for each process.

Rhythm

Closely allied to preservation of the right attitude and posture is preservation of the proper rhythm and of due coördination of the various movements that make up an operation. Just as the members of

[6] Indust. Fatigue Res. Board, Report No. 26.

[7] Ibid.

a boating eight become "ragged" in fatigue, using useless energy with relatively useless results, so the tired worker "falls to pieces;" his rhythm and skill suffer.

In the operation of roughing, i.e., removing scratches and imperfections from spoons and forks, which are pressed for the purpose against a rotating wooden leather-covered wheel, oily sand being allowed to fall between the wheel and the article that is being roughed. Farmer and Brooke[8] estimated by means of a recording watt meter, the number and duration of strokes, the pauses between the strokes and the pressure of the strokes against the wheel, as the output fell off from fatigue. They found that the number of strokes per spoon, the duration of those strokes, and the pressure with which the strokes are applied increased towards the end of the spell in spite of the fact that, at this time, when output is actually diminishing, fatigue may be supposed to be present. As they express it, the tired worker is "not only working slower than when she is fresh but is expending her energy extravagantly."

The number of strokes per spoon remains nearly constant during the morning; which is a fair indication of the maintenance of a steady rhythm. It is during the afternoon, especially towards the end, that the greatest variations occur. Just as when interest fails, constant volitional efforts have to be employed to maintain the requisite mental attitude, so when the natural rhythm fails through fatigue, conscious efforts have to be invoked to carry on the work.

[8] Ibid., Report No. 15.

It is in this sense that I ally rhythm with muscular posture and mental attitude. All three can be prolonged for some considerable time before fatigue sets in. All three may be regarded as a kind of matrix in which mental and muscular acts are set. All three require for their maintenance a directive activity which ultimately tires—an activity of the nature of which we know no more than we do of that directive activity of which it is an expression—that activity which *par excellence* distinguishes animate from inanimate nature.

Abnormal fatigue

Fatigue, in the sense of a diminution of efficiency owing to prolonged exercise, is of course a normal and healthy result of all work; it can only be considered serious and abnormal when after the rest which follows any given spell of work, it is not almost wholly dissipated. For then, spell by spell, day by day, the fatigue effects accumulate and the time must sooner or later arrive when healthy fatigue is replaced by pathological exhaustion.

Taking the daily industrial work curve and comparing it throughout the week, we actually find evidence sometimes of such accumulation of fatigue, but in general, it is practically dissipated by the week-end rest.

The amount of fatigue during the week varies with the skill of the worker. In the boot and shoe industry, for example, the most expert operative's record was found to rise throughout the week, whereas in some instances the poorer worker's began to fall from Wednesday or even earlier onwards.[9]

The influence of fatigue may be masked by spurts. Thus in silk weaving the best output occurs between Thursday morning and Friday noon, which is the "making-up time" for calculating the wages to be paid on the week's work. The approach of an annual holiday when the maximal piece-rate earnings are coveted, may lead to a similar spurt.

LENGTH AND DISTRIBUTION OF PERIODS OF WORK AND REST

The earliest attempts in Great Britain to deal systematically with the problems of industrial psychology which arose during the recent war were made by the Health of Munition Workers Committee. They concerned the proper length and distribution of periods of work and rest. There were times during the war when in Great Britain munition workers worked nominally for 74½, actually for about 66 hours a week. In one case, for example, 63½ hours were actually worked by women engaged in the moderately heavy work of turning fuse bodies. When their weekly hours of actual work were reduced from 63½ to 47½, their total weekly output rose by 13 per cent. An even greater increase in weekly output, an increase of 19 per cent followed the reduction of hours actually worked from 58.2 to 50.4 per week in the case of men engaged in the heavier work of sizing fuse bodies. Not only was the output thus increased, but a reduction in the amount of lost time through sickness, slackness, etc., also resulted. Thus in a shell factory the time lost fell from 11.8 to 6 per cent after the hours of work had been reduced from 63¼ to 54 per week; while later in the iron and steel industry a reduction of the hours of work from 53 to 48 per week was followed by a reduction in lost time from 2.46 to 0.46 per cent of the working hours.

Working hours in munitions and glass works

But although the total weekly hours now worked in Great Britain do not generally endanger serious fatigue, we are nevertheless confronted with the important problem of the best distribution of those hours so as to secure the *maximal efficiency* (which includes the maximal health and contentment) of the worker. During the war a comparison was made by the Industrial Fatigue Research Board[10] between the output during twelve-hour and eight-hour shifts among women workers who were engaged in cutting off the ends of the roughly forged shells. It was found that that part of the work which was dependent on the worker and independent of machinery, and which was performed in 100 minutes of the long-shift system was accomplished in 80½ minutes when the short-shift system was adopted. That means a 19.5 per cent improvement. Vernon[11] has since studied the output records of four British

[9] Ibid., Report No. 10.

[10] Ibid., Report No. 2.

[11] Ibid., Report No. 1.

factories in the tinplate industry. The hourly output during four-hour shifts was found to be 11.5 per cent greater than when eight-hour shifts were worked. Moreover, under this shorter-shift system the output no longer showed the serious fall at the end of each day, which occurred in the longer-shift system. Finally the amount of lost time was less.

In certain glass works in Great Britain Farmer[12] recently found that the hourly output increased by about 10 per cent when eight-hour shifts were substituted for ten-hour shifts. There was also an appreciable reduction in spoilt work and decrease in lost time when the shorter shifts were introduced. The increase in rate of output in the eight-hour shift was not in itself large enough to make the output equal to that in the ten-hour shift, but as the eight-hour shifts allowed of a twenty-four-hour use of the plant, the total daily output was higher than when the ten-hour shifts were employed, which involved only a twenty-hour use of the plant daily.

Length of rest pause

The most favorable *length of the rest pause,* and the most favorable point of its introduction can only be determined by careful expert analysis of the work curve. As the laboratory work of the Kräpelin school has shown, they vary with the worker, with the nature of his work and with the duration of its spell. In a boot and shoe factory[13] it was desired to increase the output without adding new machinery. This was effected by allotting to each double press three, instead of the usual two, girls; each of the three working for forty minutes in each hour, and resting the remaining twenty minutes. An increase of output was obtained in the six presses worked, amounting to 45, 43, 57, 39, 43 and 75 per cent respectively, the average increase of output for the six presses being over 44 per cent. The presses showing the highest increase were those worked by the least skilled operatives, in whom fatigue was doubtless most prevalent. Lost time and sickness were diminished, and a spare girl was always at hand in emergency to take the place of an absent member of the team.

Time required for improvement of output

Save in exceptional circumstances, however, the introduction of such lengthy periods of rest must prove impossible. On the other hand, the value of shorter rest pauses has been repeatedly demonstrated.

Vernon[14] has brought forward evidence to show that several months may be needed before the full effect of rest pauses may be reached. Thus in an experiment on girls making bicycle chains, it took six months. In one on labelling, it took ten weeks. Vernon has here again shown that rest pauses produce their maximal effect on the slowest workers. Thus when girls engaged on labelling were divided into three groups according to their speed of work, a ten minutes'

[12] Ibid., Report No. 24.
[13] Ibid., Report No. 10.
[14] Ibid., Report No. 25.

rest effected an improvement of 8 per cent in the quickest third, one of 17 per cent in the slowest third, and one of 13 per cent in the middle third.

Breaking long work periods

There can be no doubt that in by far the majority of operations, the efficiency of a spell of work exceeding four hours can be improved if divided into two halves separated by a few minutes' pause. Again and again, workers have testified to their appreciation of such a rest interval. The work curve is thereby not only raised in height but is also improved in form. We shall presently have occasion to examine the various forms of work curve. At the moment I wish to indicate by actual example, from an investigation at the National Institute of Industrial Psychology,[15] how a daily work curve may be improved in form. In the following instance, before the rest pause was introduced, the work curve, averaged from a number of workers, showing the output for each half-hour throughout the day, rose until 9:30 a.m., remaining at the same level until 11:00 a.m., then declining, next rising from 12:00 to 12:30 probably through the influence of end-spurt, and finally falling slightly until 1:00 p.m. when there was an hour's break for dinner. After a rest pause of seven minutes had been introduced at 11:00 a.m., not only was the curve throughout at a higher level, but the level was much more uniform than in the previous curve, indicating perhaps a lessened call on excessive voluntary effort, and more orderly, rhythmical method of work. In the afternoon work curve, under both conditions a spurt occurs at 4:30; but where the rest pause was introduced (at 4:00 p.m.) the improvement was maintained and the curve continued to rise right up to 6:00 p.m., the end of the day's work, whereas, before the introduction of the rest pause it fell during the last half-hour. When no rest pause was interpolated at 4:00 p.m., the work curve fell sharply from 4:00 to 4:30; but after the seven minutes' rest had been introduced at 4:00 p.m., the work done during the remaining twenty-three minutes of the half-hour actually exceeded that done in the same half-hour when no rest pause was interpolated. Despite a 3 per cent reduction in total working hours due to the pause, a more than 5 per cent increase in output, with less fatigue to the worker, resulted. The workers greatly appreciated the pause.

In another experiment[16] an increase of over 14 per cent in output was obtained by the introduction of a fifteen minutes' interval in the morning and the afternoon, which the workers, engaged in another factory on the same work as that referred to, spent mainly in a *change of work*, not merely in rest. They spent the pause in collecting materials, a task which had been previously carried out partly during the first few minutes of each morning's work, partly distributed irregularly throughout the remainder of the day. The output

[15] Jour. Nat. Inst. Indust. Psychol., 1922, vol. i, no. 3, pp. 89–92.

[16] Ibid., 1923, vol. i, pt. 6, pp. 236–239.

curve showed an enormous improvement in form as well as in height. The workers were unanimous in their approval of the change.

Improvement before rest pause

That a rest pause may also show an improvement of output not only after but also before the pause is indicated by the following data obtained by Wyatt and Ogden[17] in a laboratory experiment consisting of adding series of 5 digits during morning and afternoon spells of work. The percentage increases of output owing to the rest pause were

	Morning	Afternoon
Before the pause	12.1	19.8
After the pause	20.5	24.1

INTERPRETATION OF WORK CURVES

A well-shaped curve should not show too many irregularities, for these indicate the excessive play of voluntary effort and inadequate help from habit and rhythm. It should not decline too greatly towards the end of the spell or work, for this indicates excessive fatigue. Irregularities, initial rises and final falls there must always be; an absolutely flat curve is unobtainable. End-spurts may or may not be present, but they are so variable in occurrence that they cannot in general be considered as diagnostic of a good or bad form of work curve.

Farmer[18] has recently attempted to indicate the conclusions which may be drawn from changes in the shape and level of the work curve due to a change of conditions. First, the curve may remain the same in shape but be on a higher level. This he regards as signifying that a greater output has been obtained under the new conditions with the same amount of effort, and with the same fatigue effect of the day's work. Second, the curve may keep practically on the same level but now be of a far better shape. We may then infer that the operation has been facilitated by the changed conditions in the sense not that it can be performed with greater speed, but that the cumulative effects of its repetition are less fatiguing than in the original method. Third, the curve may be on a higher level but of a worse shape. Here we may assume that the increased output has resulted from a quicker and more fatiguing method of working, such as may be expected when methods of speeding up are introduced with little regard to the health of the worker. Lastly, the curve may be on a higher level and also of a better shape. When this occurs, we are no doubt justified in considering that it indicates an easier, speedier and less fatiguing method of working, yielding a higher output with less fatigue to the worker, despite the fact that he is repeating the operation a larger number of times during the day.

Variations due to individual reaction and type of work

But it must be remembered that, under otherwise similar conditions, the ideal work curve cannot be realized for *every* worker and for

[17] Indust. Fatigue Res. Board, Report No. 25.

[18] Brit. Jour. Psychol., 1923, vol. xiii, pt. 3, pp. 308–314.

every type of work. Some individuals work better in short stages and by spurts, others over longer periods and more uniformly. The rest pauses which increase the output of some workers will, as has been shown by research in this country, reduce the output of others. Moreover, some types of work are characterized by considerable muscular fatigue. In these the work curve must be expected to fall considerably towards the end of the morning's work, to show a fair recovery after the midday break, followed by a progressive, well-marked fall throughout the afternoon. On the other hand, operations requiring skill and dexterity would be expected to show a work curve rising slowly in the morning to a maximal peak, as the worker settles to his work, followed by a less obvious fall (adaptation preventing or outweighing fatigue), a less complete recovery after the mid-day break (owing to loss of adaptation), and a smaller decline towards the end of the afternoon. Again, the work curve of operations characterized by rhythmical movements may be expected to show a good increase during the morning as the worker settles down to his rhythm, after which the output is relatively well-maintained throughout the rest of the day, provided that the hours of work be not excessive.

All these expectations have been verified in an inquiry conducted on behalf of the United States Public Health Service.[19] The stability of output occurring in the case of rhythmical work was found to be still greater in machine work, a steady rise occurring up to the third or fourth hour of the day, after which there was little variation in the rate of production. But, as would be expected, these curves varied in shape according as they were obtained from an 8-hour plant or a 10-hour plant, those from the latter showing a slower rise in the morning, and an earlier and greater fall throughout the afternoon.

Characteristic curve for monotonous work

Attempts have been recently made to claim that a special form of curve is apt to appear in monotonous work,[20] the worker coming fresh to it at the start of the spell, then becoming bored with it and finally looking eagerly to its termination as the end of the spell draws near. The curve of monotonous work, if this claim be substantiated, falls in the middle of the spell and is higher on either side of it—thus being absolutely inverse in shape to the "normal" work curve which reaches its maximum not far from the middle from the spell of work.

Effects of working conditions

Lastly I must draw attention, however briefly, to the importance of such influences as lighting, humidity and temperature upon output.

The work of Wyatt, Weston and Elton[21] has shown that in the proc-

[19] U. S. Pub. Health Service, 1920, Bulletin No. 106.

[20] Jour. Nat. Inst. Indust. Psychol., 1924, vol. ii, pt. 1, pp. 18–23.

[21] Indust. Fatigue Res. Board, Reports Nos. 9, 20, 23.

ess of cotton-weaving the use of artificial light reduces output by 5 per cent, and that in the more delicate processes of silk and fine-linen weaving it reduces output by 10 and 11 per cent respectively.

In fine-linen and in cotton-weaving, Weston and Wyatt[22] have shown that owing to the discomfort and fatigue of the weavers, efficiency falls when the wet-bulb temperature rises beyond about 73°F., despite the fact that a higher temperature and a higher degree of humidity are favorable from the point of view of their physical effects on the manufacture of the material.

The effects of temperature on output are indicated by the data of seasonal variations obtained by Vernon in the iron and steel industry and by Farmer, Brooke and Chambers in the glass industry.[23]

THE COMPLEX CHARACTER OF FATIGUE

I have said enough to indicate the impossibility of defining fatigue in a way satisfactorily for the application of any tests devised to measure it. The interpolation of a test inevitably introduces a change of attitude and a change of interest or the complication of some other feeling. The subject may be gratified, be annoyed, or, as is sometimes the case, apathetic, at being called away from his daily work to the test. He may be amused or alarmed at the apparatus which is applied to him or remain completely passive. Also, he may become bored with the test to which he is repeatedly submitted. Such influences, varying at different times and in different persons, cannot fail to affect the results of a test even when it is of such a character that the worker cannot voluntarily control his behavior to it, as is the case, for instance, in measuring cardiac, vascular, or respiratory activity. If, on the other hand, the test be opened to the voluntary control of the subject, e.g. a dynamometer test or a test of adding figures, dotting circles, or erasing a prescribed letter from printed matter, we are dependent almost entirely on the conscientiousness of the subject for our belief that he is always doing his best at the test.

If we continue to use (and it is almost impossible to avoid using) the term fatigue in industrial conditions, let us remember how complex is its character, how ignorant we are of its full nature, and how impossible it is in the intact organism to distinguish lower from higher fatigue, to separate the fatigue of explosive acts from the fatigue of maintaining attitudes, or to eliminate the effects of changing interest, excitement, suggestion, and the like. In industrial psychology, our hope lies rather in the study not of fatigue tests but of the curves of actual output, endeavoring to analyse the various influences at work and to observe, by the comparison of curves obtained under different conditions, how industrial efficiency may be improved.

[22] Ibid., Reports Nos. 20, 23.

[23] Ibid., Reports Nos. 1, 5, 24.