# ECONOMICS OF FATIGUE AND UNREST AND THE EFFICIENCY OF LABOUR IN ENGLISH AND AMERICAN INDUSTRY

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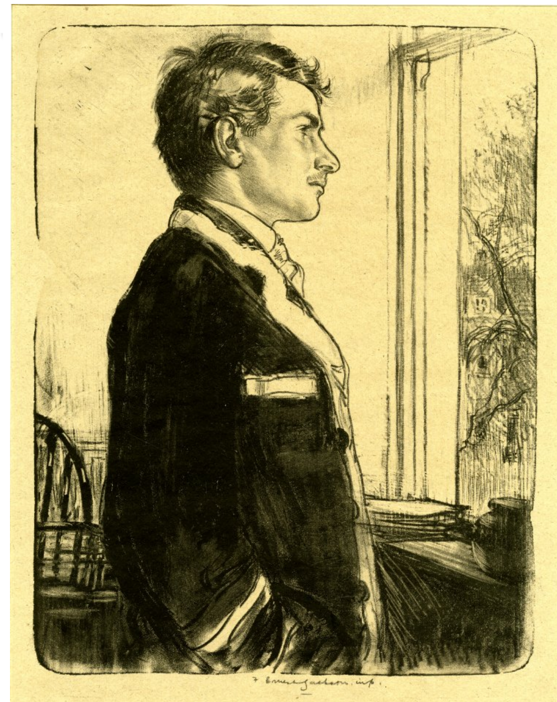

LONDON: GEORGE ALLEN & UNWIN LTD.
RUSKIN HOUSE, 40 MUSEUM STREET, W.C. 1
NEW YORK: HENRY HOLT AND COMPANY
1924

## D—Conditions of Excessive Loss

### § 1. *The General Effect of Changed Hours of Work*

Industry offers two types of opportunity for tracing the effect of hours of work on output. One (which will be dealt with in the next section) occurs " where observations can be made during consecutive divisions throughout some definite or continuous working period." The opportunity utilized in this section occurs, again to quote my manual (18),

> where the length or intensity (of activity) in any given factory or district has been changed and the resultant working capacity in the period before and after can be contrasted. Particularly in the same factory contrasts are possible where, owing to strikes or trade conditions, there is short-time or over-time, or owing to a definite reorganization (1) the total length of hours has been reduced or increased, or (2) rest periods have been introduced or cut out and the distribution of hours altered, or (3) activity generally has been intensified or slackened.

Among these possibilities conclusive results have been obtained as to the effects on output of (1) a general reduction of hours, (2) a general increase of hours, (3) an increase in hours by occasional overtime, (4) the introduction of short recess periods.

(1) In 1900 Abbé altered the scheduled hours at the Zeiss Optical Works at Jena, from 9 to 8 per day, and carefully observed the power consumed actually in driving the machinery for four weeks before and after the change. This power was found to have increased some 12 per cent. per hour. As a further check Abbé compared the piece-rate earnings of the employees for a year before and after the change, and found them to have increased 16·2 per cent. per hour. Factors other than the hours of work had been kept constant, and Abbé felt justified in attributing the former low productivity specifically to the longer hours. It will be seen that this increase in hourly output compensates for the reduction in the number of hours worked, so that the total daily output remained about constant.

Similar experiences of a low daily output associated with long working days have been found in many other classical experiments. We need only mention the work of L. G. Frommont at the Engis Chemical Works at Liège (20) in reducing the working day from a 12-hour basis to an 8-hour basis;[1] the experiment of Sir William Mather, M.P. (20), at the Salford Iron Works in England in reducing his working hours from a 54- or 53-hour week to one of 48 hours; and the experience of the British Government (6, July 1905) when a 48-hour week was introduced in 1894 by an average reduction of $5\frac{3}{4}$ hours at Woolwich Arsenal, and of $2\frac{1}{2}$ hours per week in the Admiralty dockyards. In none of these practical experiments in reducing hours to 8 a day or 48 a week did the total daily output fall, and sometimes it rose slightly.

Subsequent to these experiments an important series of records from single operations were collected during the recent war by Vernon, acting as investigator to the Health of Munition Workers Committee. In Table 28 are presented his results as summarized in the final report of that committee (3). The observations refer, broadly speaking, to a reduction of hours from a 12-hour-day basis sometimes with work on Sunday, to a full 10-hour day, usually with a week-end holiday.

[1] A 12- or 8-hour *basis* does not imply that exact number of working hours, since it includes intervals for meals. A 12-hour basis usually involves $10\frac{1}{2}$ hours actual work, an 8-hour basis $7\frac{1}{2}$ hours actual work.



Of the four operations listed, (A) is performed on a lathe and falls in the "man-operated" class in Table 2; (C) involves muscular power in turning a handle and falls in the "man-driven" class; and (B) and (E) are semi-automatic (i.e. fall in the "man-stocked" class), and are limited by the machine in their possible speed of performance.

TABLE 28

EFFECT ON OUTPUT OF REDUCTION OF HOURS *

| Type of Workers and Operation. | Weeks Ending | Average Weekly Hours. | | Relative Hourly Output. | Relative Total Output. |
|---|---|---|---|---|---|
| | | Nominal. | Actual. | | |
| (1) | (2) | (3) | (4) | (5) | (6) |
| (A) 95 *or* 80 *Women Turning Aluminium Fuse Bodies.* | | | | | |
| First period .. .. | Nov. 14–Dec. 19 | 74·8 | 66·2 | 100 | 100 |
| Second period .. | May 14–July 2 | 61·5 | 54·8 | 134 | 111 |
| Third period .. .. | Nov. 11–Dec. 23 | 54·8 | 45·6 | 158 | 109 |
| (B) 40 *Women Milling a Screw Thread.* | | | | | |
| First period .. .. | Nov. 21–Dec. 19 | 71·8 | 64·9 | 100 | 100 |
| Secondperiod .. .. | July 16–Aug. 6 | 64·6 | 54·8 | 121 | 102 |
| Third period .. .. | Oct. 14–Nov. 18 | 57·3 | 48·1 | 133 | 99 |
| (C) 56 *Men Sizing Fuse Bodies.* | | | | | |
| First period .. .. | Nov. 14–Dec. 19 | 66·7 | 58·2 | 100 | 100 |
| Second period .. | Feb. 27–April 16 | 62·8 | 50·5 | 122 | 106 |
| Third period .. .. | Nov. 11–Dec. 23 | 56·5 | 51·2 | 139 | 122 |
| (E) 15 *Boys Boring Top Caps.* | | | | | |
| First period .. .. | Nov. 15–Dec. 19 | 78·5 | 72·5 | 100 | 100 |
| Second period .. | May 1–May 28 | 61·5 | 54·7 | 117 | 88 |
| Third period .. .. | July 3–Sept. 23 | 60·5 | 54·5 | 129 | 97 |

* Figures are quoted from (1, No. 20) Tables A, B, C and D.

Column 3 gives the nominal scheduled hours which are seen to be lowered gradually for each operation; column 4 gives the actual hours worked, i.e. scheduled hours minus hours of absence, which also fall with the scheduled hours. The result on the hourly output rate is expressed in column 5 as a percentage of the output during the longer hours. This hourly rate of output, it will be seen, increases universally with the decrease in hours. In other words, the low hourly output of the earlier periods in each of the operations studied seems to be due to the length of hours of work. In the 6th column is shown the total daily output. If the hourly rate of output rises while the actual number of hours worked falls, it remains of course undetermined whether the total result will be a rise or fall in output.

Vernon's results show that, on the whole, as a result of reducing hours from about 70 per week to about 55, i.e. roughly from a 12-hour-day basis to a 10-hour-day basis, the increasing hourly rate of output more than outbalances the reduction in hours, and the total daily output is increased.

Investigations into a further reduction of hours were made by Vernon (4, No. 1) in the tinplate industry of South Wales. In millmen's work the *hourly* output rate increased 4·7 per cent., 8·5 per cent. and 10·6 per cent. in three factories, when hours per day were reduced from 8 to 6, and increased 11·5 per cent. in one factory when the hours were reduced from 8 to 4. It is clear that in no case was the total daily output quite as high under reduced hours.

Vernon shows that a reduction of hours may not be followed immediately by a rise in the rate of output. There is usually a period of "adaptation" to the altered hours. (4, No. 6.)

When the hours of work are reduced, there is often no change in the hourly output for several weeks. Then it begins to mount slowly, but it takes a long time before it attains a steady value in equilibrium with the altered hours. The adaptation period was found to be about two months when the hours of tinplate millmen were reduced from 8 to 6 per shift, but 13 months when those of open-hearth steel melters were reduced from 12 to 8 per shift. In fuse operations it varied from two to four months, and in big shell operations from two months to six months or more. The time required cannot be predicted, but it is usually shorter in the simpler operations than in the more complex ones.

In recent years the hours of work have been reduced in all English and in many American industries, but the opportunity has been missed of studying on a large scale, and yet scientifically, the effect on output. Results can be quoted only in a few isolated cases. It is true that the American National Industrial Conference Board have issued "research" reports on the effect of hours on output in several industries and have summarized the various results



obtained. But the data tabulated in these reports are at worst only opinions, and at best statistics provided by the management, and likely to be biased by the hopes and desires of the informant. These results cannot be cited as of equal scientific validity with the results of the experiments and observations mentioned above.[1]

As far as the evidence goes the effects of reducing hours of work can be summed up somewhat as follows:

Reduction from a 12-hour to a 10-hour basis results in increased daily output; further reduction to an 8-hour basis results in at least maintaining this increased daily output; but further reduction while increasing the hourly rate of output, seems to decrease the total daily output.

These results were obtained mainly in the type of work where the speed of operation depends fairly equally on the human and the mechanical factors. Probably where machinery predominates in setting the pace, a reduction of hours would result in less rise or greater fall in output; and where the human factor predominates, as in sizing fuses, there would be greater rise or less fall.

Machinery and technical processes, for instance, tend to set the pace in steel-making by the open-hearth process, and here, from the evidence of four years' records, Vernon found that three shifts of men working 8 hours each were able to increase output at times 18 per cent., but on the average only 7 per cent. over that of two shifts of men working 12 hours each. Actually this means that one 8-hour shift produced considerably less than one 12-hour shift.

It is not possible to estimate the course of events for whole industries. An industry consists in a group of firms all attempting to satisfy some particular need or engaged on some particular material, and each employing innumerable

[1] These specious methods did not pass uncriticized at the time. The Lancashire *Cotton Factory Times* of June 14, 1919, finds in one of the reports on the cotton industry "a distinct suggestiveness of a desire to minimize the importance of cases where production was maintained in spite of reduced time," and thinks "the statistics are admittedly to be taken with a grain of salt." *The Times* points out, further, that the manufacturers interviewed . . . "are the men who in the past have fought tooth and nail against the time reductions that the legislature has been prevailed upon to enforce, and that in view of a possible further reduction it is easy to understand why the manufacturers have no particular incentive to report favourably on past results of shortened hours."

operations, occupations and types of work; and it is the specific type of work that will determine the effect of changes in hours on output, not the heterogeneously composed "industry." There is much more in common physiologically between the work of a common labourer in a steel mill and a common labourer in a textile mill, or on a railway, or in building operations, than between the work of the steel-mill labourer and the steel-mill mechanic or draughtsman.

(2) The investigations quoted so far have all dealt with the results of a reduction of hours. Since there is always the chance that the resultant improvement in the hourly rate of output of given workers may be due simply to the later stages of learning, a more satisfactory experiment, scientifically, is to observe whether hourly output will fall with an increase in hours. Vernon found that when tin-plate mill men were changed back from 6-hour shifts to 8-hour shifts, their output fell without delay to approximately the old level found on the 8-hour shift; i.e. it fell some 11 per cent. to 14 per cent. There was, in fact, little or none of the gradual adaptation observed in the reverse change of shifts.

Results (hitherto unpublished) that I obtained in a highly organized English munition and engineering factory are worth quoting in this connection. In the first year of the war, hours of work were increased from $8\frac{3}{4}$ to $10\frac{1}{2}$ hours per day, and a heavy fall in the output rate was experienced. Among eight girls who happened to be engaged on the same operation for a sufficiently long period before and after the increase in hours, I found the hourly output of five to have fallen by 14 per cent. on the average, while that of two girls remained constant and that of one rose 2·5 per cent. On the average, the fall in the hourly output as a result of the addition of $1\frac{3}{4}$ hours of work was equivalent to the loss of about one hour's output at the old rate of efficiency.

(3) In American munition plants the normal hours worked were not, as a rule, increased on the country's intervention in the war, but overtime became more frequent. To disclose the effect of this overtime I compared the average rate of output during a normal 10-hour day following a normal day, during days when overtime was worked, and also during



normal days after days with overtime.[1] The operation on which these observations were made was that of loading the ring of the fuse with powder trains. Seven operations were successively performed, each by a different man; placing the ring in a jig covered by a housing, pouring in the powder, distributing the powder, fitting on the rammer, ramming in the powder, taking the ring and jig out of the housing, and, finally, taking the ring out of the jig.

Two groups of observations were distinguished. Records of 34 men for an average of 26 days each (Group A) were more complete as to normal days after days of overtime, and were taken at a time when the working force was stationary and new workers were not hired except to replace the old. Records of 49 men for an average of 20 days each (Group B) were taken at a time when gaps among overtime workers were filled in by new workers. This might have tended to lower the relative output of all men during overtime, but would not affect the relative output on normal days after overtime.

It was found that when overtime of $2\frac{2}{3}$ hours was added to the 10 hours normally worked, the *hourly rate* of output throughout the day of the two groups of workers, (A) and (B), loading the powder ring of the fuse fell 6·5 per cent. and 5·6 per cent. respectively from the level obtained on normal working days of 10 hours following upon a normal working day. In these same groups it was also found that there was a fall of 3·9 per cent. and 4·9 per cent. in the hourly rate of output of the same individuals when working a day of normal hours after a day with overtime.

The wages cost of overtime can be measured as the relation between the additional output obtained by the increased number of hours worked and the excess wages paid, and estimates are worth making in the case of the Group A records.

As compared with the output and cost on normal 10-hour days following a normal day, the *total daily* output of days when overtime of $2\frac{2}{3}$ hours was worked was increased by 18·4 per cent., but the cost (time and a half being paid

[1] This investigation was first summarized at the Liverpool meeting (1923) of the British Association for the Advancement of Science. Cf. (19).

during overtime) was increased by 40 per cent. On a normal day after an overtime day the output was 3·9 per cent. less.

It follows from this that if overtime was worked on two days of the week, one of these days immediately preceding a normal day—an arrangement that seems to correspond to the facts in the department investigated—the increased output for the week would be 5·48 per cent. but the increase in wages cost would be 13·33 per cent.

Or again, if we isolate one day with overtime and a normal day following it, and compare the output and wage costs with that of two normal days following a normal day, we find an increase of 7·25 per cent. in the output, but an increase of exactly 20 per cent. in the wage cost. In short, the increased output is paid for not, as appears at first sight, at a rate of 1½ the normal rate, but at slightly more than 2¾ times the normal rate.

(4) Direct comparison may also be made of the productivity before and after the introduction of short recess periods. Thus the U.S. Public Health Service (9) tried the effect of a recess period of ten minutes inserted in the middle of each of the 5-hour spells at the 10-hour plant. These were introduced as soon as a series of control observations were completed to find the rate of output *before* the change. After the change was made observations were continued on the same set of workers for several weeks.[1]

In the first few weeks of the innovation, if we consider only such operations as employed more than two persons, we find an average rise in total daily output for the different operations of from 0·86 per cent. to 7·9 per cent. This means that the increased efficiency entirely compensated for the twenty minutes lost during the day, and secured some benefit in addition. In one operation only was there a fall. In the largest group—fourteen women painting a solder mixture on the back of small army coat buttons—the rise was 1·96 per cent. In a group of men on three operations, buffing and colouring safety razor parts on a revolving wheel, the rise was 0·86 per cent., 1·1 per cent., and 1·1 per cent., and this in spite of such a strong opposition on the part of the men to "being coddled" that recess periods had soon to be abandoned in their case.

A second period of observation of the recess periods was obtained in some of the operations, when larger increases were registered in the output. The one operation where a fall had been found before, now showed a rise in output over the control period of 7·1 per cent. The other operations varied in rise from 3·26 per cent. to 18·3 per cent. In one soldering operation a third period of observation was possible, when the rise over the control period was 25·9 per cent.

It should be stated that in all cases the workers were thoroughly experienced, and that the date of their first working at the operation studied is tabulated. The fact of learning, cannot, therefore, account for the rise in output.

Recess periods were also introduced at the eight-hour factory, but met with little success in increasing output. Since the departments given recesses here contained machine operations where the state of the human working capacity is less easily read in the output than is the case with pure handwork, the results may not be significant. In so far as they indicate anything to our purpose, it is that continuous four-hour spells are harmless where continuous five-hour spells are not.

[1] This summary is quoted from my article in the *Economic Journal*, June 1920: "An Official American Investigation into Industrial Fatigue."



## § 2. *The Cyclical Effect of Continuous Hours and Days of Work*

The second and more indirect method of tracing the effect of hours of work is by means of the hourly or daily curve of output. The course of output is traced throughout the day or week by hourly or daily measurement, on the theory that the effect of continuous hours of work unrelieved by appropriate rests will show itself objectively as the working spell, day or week proceeds.

The "work curve" is the expression generally adopted to describe the results of this type of investigation, but the true inwardness of the matter is not realized until we think of the work curve as only a part of a whole cycle containing within itself a phase of rest. Elsewhere (18) I have defined this cycle as "an alternation of activity and relaxation which recurs over and over again in the life of the worker." The day forms such a cycle and also the week, the "phase" of relaxation being in one case the night's rest, and in the other a whole week-end. Months and years—unless the wage-earner is fortunate enough to obtain a yearly holiday of sufficient length—are not cycles, and a very different interpretation must be put on a fall of output during, say, a month or a year than during a day or a week. In the one case there is an opportunity to recover and to make good the fall; in the other case there is no such opportunity. The fall, as far as can be judged, is cumulative.

The method of the output curve is described in detail in my manual (18), and I have used it extensively in reporting for the British Association Committee on Fatigue from the Economic Standpoint (12) and in investigating the 8-hour day motor plant and the 10-hour day metal plant for the U.S. Public Health Service (9). This method has the advantage that there is no necessity of waiting for a change in the schedule of working hours, and that other industrial conditions besides hours are not likely to change from one hour to the next or one day to the next.[1] A mass of evidence has accumulated which it is impossible to give in full. For details reference must again be made to the paper cited above (19).

The general type of *hourly* output curve is one that rises and then falls during the course of each spell of continuous work. Where the spell is of four hours or more the peak usually occurs in the second or third hour. This curve cannot be attributed to any physiological fluctuation that would occur even if no work were done, since such fluctuations as have been measured seem to be diurnal in span, i.e. form a curve spread over the whole day and not over particular hours corresponding with the spell of work in the factory. Further, this curve can be spoken of as typical; it is not a mere compromise between two or more divergent curves but tends to be the curve most frequently shown. Deviations therefrom shown by particular workers and particular days seem distributed around it as might be expected from chance errors. Nor, as far as my evidence goes, do the less productive individuals have the more precipitous curves (19, V, § 3).

Now this typical work curve, as it may be called, is a result of variation not merely in the speed of work while at work, but it is also a result of variation in the time taken off from work voluntarily by the worker.

Time wasted involuntarily by the worker owing to machine stoppage, starting up, etc., is allowed for as explained in Chapter XIII and does not affect the curve.

[1] See "Methods for Field Study of Industrial Fatigue" (10, No. 458).



But the curve *is* affected by the time voluntarily spent in resting, chatting, and in other relaxation which, among night workers, will probably include sleeping.[1] Though to some extent scattered throughout the working spells, these rests occur mainly in the first and last hours and account partially for the low output in these hours, but only partially. The actual speed of work seems also to be lower in these hours. Table 29 is summarized from unusually detailed

TABLE 29

PAUSES AND RATE OF WORK IN THE FIRST, LAST AND MIDDLE HOURS OF THE SPELL

Grinding Springs: American Ten-hour Plant

| Hour of Day. | Average Hourly Pauses in Minutes. | | Rate of Work, Minutes per Piece. |
|---|---|---|---|
| | Involuntary. | Voluntary. | |
| 7–8 | 6·00 | 0·36 | 0·45 |
| 8–11 | 1·94 | 1·35 | 0·44 |
| 11–12 | 11·40 | 1·70 | 0·45 |
| 1–2 | 4·02 | 0·06 | 0·50 |
| 2–5 | 1·36 | 0·80 | 0·46 |
| 5–6 | 10·98 | 3·51 | 0·47 |

observations of the operation of grinding springs[2] when account was taken of pauses of even less than three minutes' duration.

The rate of work while working was obtained in the case of each hourly observation on each day for each worker, the method being to subtract the minutes lost from the sixty minutes constituting the hour, and to divide the resultant minutes actually worked by the number of pieces made. The rate of speed is thus expressed as minutes spent per piece; it is seen to be slow in the first and last hours of each spell,

[1] Observations which I and my associates made in America of 74 men every quarter of an hour through a 12-hour nightshift disclosed the following interesting data: 3.30 a.m. 5 men asleep; 5 a.m. 5 men asleep (not necessarily the same); 5.45 a.m. 4 men asleep; 6.15 a.m. 14 men asleep: 42 per cent. of the men were found asleep at one time or another between 5 and 7 a.m.

[2] The full table appears elsewhere (15, vol. I, No. 5) and a description of the operation of grinding springs is given in Chapter IX.

i.e. a larger fraction of a minute was required per piece quite apart from any increase in pauses.

Moreover, it is the involuntary and unavoidable pauses that are high in these hours rather than the voluntary, avoidable pauses. It is probable, therefore, that the low points in the hourly output curve found at the beginning and end of each work spell of the daily cycle are not due merely to the increase of voluntary pauses. A slowing-down seemed to occur contemporaneously in the actual working rate.

As far as the evidence goes, the shape of the hourly work curve is influenced mainly by three factors: (1) The total length of the working day and the total length of the spells of continuous work; (2) the type of work engaged in; (3) the presence of any tendency to deliberate restriction of output.

(1) The longer the total working day the greater will be the variation between the output of the several hours, and in particular the greater the fall toward the end of each spell. Vernon has shown (4, No. 1) that in tinplate manufacture hourly outputs vary less from one another during a 6-hour working day than during an 8-hour day, and that the middle period of low output is less prolonged. And the 8-hour day shows the same advantages when contrasted, in turn, with the 10-hour day.

Furthermore, when a 12-hour nightshift was worked by the 10-hour plant the average output dropped 39 per cent. below possible efficiency in the last hour but one, and dropped practically to *nil* in the last hour.

Composite curves *representative of the same types of operation* in the motor plant working the 8-hour day and the metal plant working the 10-hour day (9) showed that on the average the hourly output at the 10-hour factory fell 9·8 below the possible efficiency [1] of the plant and at the 8-hour factory only 6·0 per cent. below. The fall in output towards the end of each spell was considerably greater in the 10-hour plant. In the last hour of the day, even when allowance was made for stoppage of machinery,

[1] For methods of representing the same types of operation and of calculating the possible efficiency of each plant, reference must be made to Public Health Bulletin 106 (9), pp. 11–15.



etc., the 8-hour plant had an output rate 10·2 per cent. below its own possible efficiency, but the fall was 20·9 per cent. in the 10-hour plant.

A composite curve of output for the 10-hour plant is presented graphically in Table 40, which is formed by taking the average of the output curves for muscular handwork, the output curve for dexterous handwork, and the power consumption curve for all machine work.

The average level of output of the afternoon spell is usually lower than that of the morning spell, where the hours of work are ten or more, and this in spite of the very low output often found in the first hour of the morning. If overtime is worked or a spell before breakfast, the level of output in these additional periods is markedly low and the superior productivity of the so-called one-break system is evident.

(2) That differences exist in the curves of operations of different type suggested itself to me when collecting evidence for the British Association Committee. In drawing up the report in 1915 I showed that operators working on machines such as stamping presses maintained their rate of output almost up to the end of the working day in contrast to those engaged in handwork such as confectionery making, and soldering, straightening and labelling of tins, where the fall at the end of the day was most marked.

Evidence gathered since then at the American 8- and 10-hour plants confirms the view that the shortest initial rise, if any, and the greatest fall in the curve of output during the spell and the day, is seen to occur on muscular, and next on dexterous, handwork; and the least rise and least fall on machine work in both 10-hour and 8-hour plants. The hour of maximum output is the second on muscular handwork in both plants, and the third on dexterous handwork again in both plants. On machine work, however, the maximum hour comes later; it is the fourth in the 10-hour plant and the third or fifth in the 8-hour plant. The hour of minimum output is the last in all handwork, muscular or dexterous, but in all machine work the first hour is that of minimum output.

Comparing the average output of the second spell with that of the first, there is a further remarkable agreement on the relative standing of the four types in both the factories. In the 8-hour plant lathe machine work shows on the average a rise of 2 per cent. in the output of the second spell, miscellaneous machine work a rise of 1 per cent., dexterous handwork a fall of nearly 3 per cent., and muscular work a fall of nearly 5 per cent. In the 10-hour plant the order is precisely the same. Lathe machine work shows the same 2 per cent. rise in the output of the second spell as compared with that of the first; in miscellaneous machine work the output of the spells is the same (when combined with lathe work, as in Table 40, the rise is 0·7 per cent.); in dexterous handwork the second spell is down about 6 per cent.; and in muscular handwork it is down almost 10 per cent. In spite of some exceptions, there is also a striking uniformity in the output curves of the individual operations within each type.

The hourly output curves in the 10-hour plant for combined machine work, for muscular, and for dexterous handwork are presented graphically in Table 40. These types of work do not, of course, exhaust the varieties of work to be found in industry, nor do the individual operations by any means represent all the species within the type.

Muscular handwork includes operations of the type marked 4 and 5*a* in Table 2, i.e. body work and man-driven machines; dexterous handwork corresponds to the handwork numbered 2, and lathe machine work to the man-operated type marked 5*c*. Among miscellaneous machine work are chemical treatment (5*f*), man-fed (5*d*), and man-stocked types (5*e*). Output from chemical treatment, as represented by furnace work, can be isolated at the 8-hour plant (19); it shows a continuous rise throughout the first spell, and throughout the second spell a continuous though much slower fall.

Lathe work, when isolated as in Bulletin 106 (9, p. 59), or as by Vernon during the nightshift, shows a buoyancy in its curve surprising for operations often so heavy. This may be connected with the pauses exhibited throughout the spell. On larger lathes the operator must remain inactive



for long periods while the machining is being completed; on the smaller lathes, possibly to secure a rhythm (see p. 246), the work seems to be done voluntarily in a series of runs with intervals between.

I have also obtained work curves in the "sense work" (type 3 of Table 2) of women weighing brass samples (9, p. 186), and craft work (type 6) of printers setting type (13); and Baumberger and Martin have obtained curves for the clerical work (type 1) of telegraphists. On the whole these curves conform to the general rule of a rise followed by a fall in each spell, and a lower general level in the later spell.

Quite recently also, a thorough investigation has been made by Wyatt (4, No. 23) of the work of tending automatic looms weaving cotton (type 5*f*). Since on "automatics" the rate of output is so largely determined by the machine, measurement was concentrated on the time spent by the operative attending to loom stoppages. "An initial rise and final fall in efficiency" was then "discernible in the daily work curves," and these were "not due (as is sometimes alleged) to extraneous causes such as lateness in starting, etc., but are of subjective origin and represent a real quickening up and slowing down. . . . The time required to attend to loom stoppages is greater in the afternoon than in the morning spells of work, and increases progressively throughout the day." In fact, under constant conditions of temperature and humidity the morning spell shows a fall from maximum "working capacity" of 1·0 per cent. in the third full hour and 4·8 per cent. in the fourth; but the afternoon spell shows a fall of 5·1 per cent. in the second full hour, 7·2 per cent. in the third, and 12·7 per cent. in the fourth.

It is evident that a curve exists even in the apparently most cut-and-dried mechanical operations, and that differences of curve on different types of operation are largely a matter of degree.

It must be realized, however, that "owing to the statistical necessity of securing a frequently and regularly repeated output" (12), the varieties of work for which an hourly output curve can be obtained are limited. For the output, however variegated, of power-driven machines the curve of power consumption is an effective substitute; but for much muscular work such as sweeping up or carrying materials there is no measured output curve obtainable.

(3) In operations where evidence of restriction of output is found in the narrow and skew distribution of outputs or the wide divergence from the average rate of output during spurts,[1] a peculiar hourly output curve occurs. The curve is marked by a distinct maximum in the last hour but one of each spell. The possible explanation is that working just fast enough in the first three hours of the spell to get their daily stint accomplished, workers will, in the last hour but one in the spell, and especially in the last hour but one in the day, increase the pace in order to pile up a reserve. For should there be no reserve, loss of time through mechanical breakdown or other unavoidable cause in the last hour would entail irretrievable failure to accomplish the "stint."

As regards variations in output in the course of the weekly cycle, most investigators seem to agree in finding a relatively low output on Monday, a high output in the middle of the week, and a fall towards Friday. On Saturday a new factor is introduced in that there is usually a half-holiday, and the effect of the position of this day at the end of the work phase of the weekly cycle is partially obliterated.

As a rule, however, the variation in the output of the several days or nights of the week is only slight, and is distinctly less than the usual variation between the output of the several hours of the spell or the day. The one heavy fall in weekly curves of output is that recorded (1, No. 18) among women and girls making rifle cartridge cases on a 12-hour shift, six nights a week. On four separate operations the output of the last working night of the week (Friday) was 96·9 per cent., 91·0 per cent., 89·0 per cent., and 85·1 per cent. of the average level of output throughout the week. In the latter case girls are stated to have been employed, in the other cases women.

In cotton weaving Wyatt has recently (4, No. 25) managed to collect a weekly curve of efficiency in dealing with loom stoppages[2] *measured hour by hour*, and he finds that the

[1] These spurts usually occurred after time had been lost involuntarily through breakdown of machinery, etc. See 9, pp. 84–93.

[2] See above, p. 239.



daily curves vary according to the day of the week in which they were collected: "There are signs of a progressive change in the shape and direction of the morning curves during the course of the week. The point of maximum efficiency tends to move from the end of the morning spell on Monday to the beginning of the spell on Friday, and occupies intermediate positions on the other mornings of the week. Under normal conditions, undisturbed by temporary incentives to work, the efficiency on Monday morning is relatively low."

Monday has, however, the highest afternoon record and Tuesday the highest record for mornings; after that the fall in efficiency is continuous both for the afternoon and morning spells of the successive days of the week, and the rule holds that as the daily output falls from a high level on Tuesday down to a low level on Friday, the hourly output begins falling earlier and earlier in the day.