CoA Note No. 54

THE COLLEGE OF AERONAUTICS

CRANFIELD

POST NUBES LUX

COMPENSATING REST ALLOWANCES

by

R. M. BELBIN

NOTE NO. 54
OCTOBER 1956

THE COLLEGE OF AERONAUTICS

CRANFIELD

COMPENSATING REST ALLOWANCES: SOME FINDINGS AND IMPLICATIONS FOR MANAGEMENT ARISING FROM RECENT RESEARCH.

BY

R. M. BELBIN M.A., PH.D.

DEPAR. MENT OF AIRCRAFT ECONOMICS & PRODUCTION

LIST OF CONTENTS

PREFACE

In November 1953 a research project was started at the College of Aeronautics to study Work Study rating, rest and fatigue allowances. This project has been carried out under the sponsorship of the Department of Scientific and Industrial Research with counterpart funds made available through the Conditional Aid Scheme.

At the commencement of this project it was agreed that our special concern would be rest allowances and that we would consider rating only in so far as it became a necessary part of our study of rest allowances.

This report is not intended to present results covering the whole of our investigations. The work carried out by J. A. C. Williams who was my colleague in research until April, 1956 has been presented in previous reports and these are refered to in our list of references. Mr Williams has been especially concerned with the problem of heat stress and with the determination of a rational basis for Compensating Rest Allowances in relation to known heat loads.

While this report cannot be regarded therefore as comprehensive it is hoped that for the general reader it will, however, cover sufficiently wide ground to justify some of the general conclusions that are reached at the end of this paper.

SUMMARY

In the first stage of our project some investigations were conducted into a number of industrial operations including some of a very arduous character. The method of investigation included recording of pulse count during the various stages of the work, measurement of Element and Cycle times by use of a photographic technique throughout the day for a period of days and investigation into rest breaks taken during the work.

The results were as follows:

1. The pulse count was found to indicate fairly consistently those parts of the Cycle which required high physical exertion. However, tendencies reported in laboratory studies for pulse counts to show progressive increases following prolonged periods of work or slow recovery rates were not repeated in our industrial studies.

2. Element and Cycle times showed no general pattern of change throughout a day but there was some evidence of a slowing up on heavy work requiring considerable bodily movement for a period following the lunch break. On some operations there was a tendency for workers to avoid heavy work at this period.

3. In only a few cases were operations found where the pattern of work periods and rest breaks differed to any marked extent from the normal pattern within a firm or industry. However, at the extreme end of the scale, where heavy work was combined with intense heat stress, workers engaged on piecework were found to work for little more than 6 hours a day.

In the second stage of our investigations a survey was carried out into the type of work where rest periods taken by operators were larger than those normally taken in the firms concerned. This study revealed that the type of operation found to be associated most commonly with rest breaks longer than normal was work making high and continuous demands on attention and concentration. Critical inspection operations fell especially into this category. When additional rest periods were not taken on this class of work there was evidence that the quality of work suffered.

The results of these investigations cast doubt on the common practice of providing widely varying allowances for multifarious factors that are involved in work since marked variations in rest breaks or Element and Cycle times seldom occur in practice. These results also imply that in most systems of Compensating Rest Allowances there is a tendency to over emphasize physical fatigue and to under emphasize mental and perceptual fatigue.

During the latter part of the investigation new methods have been developed for measuring efficiency on inspection operations of the type on which positive fatigue effects have been found. These methods have been found to be of considerable interest to firms concerned for purposes other than research and partly for this reason the research itself has been easier to conduct than hitherto. It is only at the time of writing, however, that these techniques are beginning to bear fruit.

INTRODUCTION

Since 1816 when Robert Owen first showed that a working day of $10\frac{1}{2}$ hours could produce an output equivalent to the 16 hour day that was being worked in most of the cotton mills of Lancashire it has been known that human fatigue is a factor that sometimes exercises an important influence on industrial performance. However, with the shortening in the length of the working day, the technical improvements in the control of ventilation and atmosphere and the progressive reduction in heavy work due to increasing mechanisation and the use of mechanical aids it is clear that human fatigue must of necessity be of more limited importance in industry than hitherto. But how important still remains unknown.

The growth of work measurement and time study have been accompanied by the recognition that a certain percentage of the period allotted to productive work must be reserved for personal relaxation. These periods vary in many cases from operation to operation according to the differences in the extent to which fatigue is assumed to be involved in the work. The allowances which are made for the personal relaxation are commonly known as Compensating Rest Allowances.

The aim of this paper is to present some of the results of research into Compensating Rest (C.R.) Allowances and the evaluation of the problem in the light of these results.

METHOD OF INVESTIGATION

The object of Compensating Rest Allowances is to enable an operator to take such personal relaxation in the day as will enable him to maintain a 'standard' performance without the occurrence of undue fatigue. A 'standard' performance refers to a rate of working one third higher than the basic or normal rate which the time study observer assesses as being appropriate to the payment of the basic rate.

If C.R. Allowances are to be appropriate to the work to which they are applied it would seem necessary to ascertain

1. whether these allowances match the personal delays that are taken,

2. whether a standard performance is maintained throughout a working day without any reduction in the rate of work being evident at any particular period of that day, and

3. to what extent undue fatigue may be experienced by operators in the maintenance of a standard performance.

The first and second problems have entailed the study of operator performance throughout the working day, but in the case of the first problem this information has been supplemented in the latter stages of investigation by information of a less detailed character obtained through examination of the variations in formal rest breaks over a wide range of operations.

Operator performance itself could be studied by two methods, either by carrying out work measurement throughout the day, that is by using the methods of a time study observer engaged on a production study, or by use of some automatic method of recording performance. Of these two methods the latter was preferred being judged as less likely to influence the situation studied than the presence of an observer. Moreover even if some response is made initially to the presence of automatic recording apparatus habituation usually ensures that after two or three days there is a return to normal behaviour.

The automatic method chosen for recording performance was the method of memo-motion or spaced shot analysis. The equipment developed for this consists of a Bolex camera to which a timing mechanism has been attached whereby an electrical impulse is fed into the camera at given intervals (8). Thus the number of frames taken per minute is determined and can be varied at will of the investigator. During the early stages of investigation it was discovered that for the information derived from the film to be meaningful it was often necessary for frames to be viewed in close sequence, preferably at $\frac{1}{2}$ second intervals. Such a setting, however would tend to prove very uneconomical in film. For this reason a further modification was carried out which rendered it possible to take two different types of sample during the day. The first sample was sufficiently detailed to provide a record and the time for an Element or Cycle of work, while the second sample afforded information as to the type of activity or the inactivity that occurred between the more detailed samples. While it was possible to adjust the settings of this double sample technique in all our studies, it was only necessary to employ a two minute sample at two frames per second followed by a sample of one frame per twelve seconds for a period of 18 minutes. An example of the type of record obtained in the more detailed sample is shown in Figure 1.

To obtain some measure of the 'heaviness' of the operations studied, one of two procedures was followed. Either the metabolic cost was estimated on the basis of the synthetics and information collected by Spitzer (reported in Lehmann, 6) or an attempt was made to measure the metabolic cost by using the M.P.I. Pulse Counter at some time during the experiment. The modification of the M.P.I. Pulse Counter to permit the use of telemetry has already been described in a previous paper (14). The effect of this was to make possible the assessment of the calorie cost of Elements of the Cycle during the period of working (see Figure 2).

Later improvements facilitated this recording by fixing the counter to the camera such that the number registering on the counter would be seen against the working position of the operator (see Figure 3).

RESULTS

The operations studied in our first series of investigations consisted of hand-drawing of bricks from a kiln, hand-rolling of steel billets, wood machining[x], tread removing in a tyre remoulding works, pressure die casting[x] (studied by J.A.C.Williams), charger driving in a steel works, preboarding in a stocking factory[x] and three shovelling operations in the fetching, shovelling and stoking of coke in a boiler house, shovelling cement with concrete moulds in a factory making precast concrete units and shovelling swarf into a centrifuge for oil extraction.

The Energy Cost of Work

In order to estimate the metabolic cost of the operations, the M.P.I. Pulse Counter was used in such a way as to enable the energy cost of work to be related to the various Elements in the Cycle. Thus operations could be compared with one another in 'heaviness' and it was possible to observe any trends in the physiological cost of work arising from prolonged periods of working. An example of the type of record obtained may be seen from Figure 5. Lifting up the laden barrow in the hot kiln (in this case with a radiant temperature of 138°F) and pushing it forward on a brick dust floor and out into the open for unloading constituted the most fatiguing part of the work. Not only would the peak pulse count be reached during this Element but the effects of the high energy cost could be seen in the comparatively high pulse counts in some cases in the succeeding Element which was the comparatively light unloading of the barrow.

Lehmann (6) has postulated the theory that the most convenient index of fatigue on heavy work is the Pulse Recovery Sum, i.e. the number of pulses following the cessation of activity which occurs before the normal pulse is regained. As a trial on the effects of prolonged activity of a heavy task a pilot experiment was carried out in the laboratory involving the lifting of ten 56 lb weights from a bench top (2ft 9ins) five feet to the floor and back again in a Cycle time averaging about 2 mins 40 secs. Thirty seconds rest was allowed between each Cycle. At the end of 5 Cycles the average pulse count was recorded as 160-170 beats per minute. One hour after the cessation of work the pulse count remained 10-15 beats per minute higher than the normal (the pulse count of the same subject at the same time on other days when no experiment took place).

[x] Film recording only.

In the case of the hand-drawing, however, study of five workers over a period of several weeks revealed no tendency for a rise in pulse count to manifest itself towards the end of a work period or of the working day once a certain number of Cycles had been completed. Nor was any greater inertia in pulse recovery apparent at the end of the day than during earlier periods. Similar results were obtained with the smaller number of studies carried out on the other operations. These operations, however, were less arduous except in the case of hand-rolling which the pulse count data revealed as of comparable heaviness, i.e. 130-140 beats per minute were reached in the heavier Elements of the job. In general it would appear that on work of this heaviness the pulse count rises steadily for the first $1\frac{1}{2}$-2 minutes but thereafter becomes stabilised.

Our studies of heavy work in industry have not then produced results which are in line with those found in laboratory studies, so that conclusions on the value of the Pulse Recovery Sum as an index of fatigue on the present evidence must remain a little indefinite. It must not be overlooked that the men studied in industry were both physically fit and accustomed to the task. But it cannot be doubted that some of them were working under extreme conditions. The arduous nature of the work may, for example, be indicated by the fact that both on the hand-rolling and the hand-drawing men were seldom able to continue in their job after the age of 50, choosing instead to move to lighter but less well-paid work.

Investigations into Element and Cycle Times

Analysis of the pattern of Element and Cycle times for the operations under review did not show any marked variation according to time of day. This was of special note and interest on the two heaviest operations, hand-rolling and hand-drawing, as the tempo of work was high. For example the lifting of the loaded barrow and moving it out of the kiln involved high static effort with the apparent result that the worker carried out the operation at a near run and the other Elements of the Cycle were performed at a similarly brisk pace.

On the shovelling operations there was some indication, however, of a variation in Element and Cycle times, except in the coke shovelling which was only an intermittent operation. Thus on swarf shovelling there w s some tendency for Element times, i.e. number of frames per shovelling of swarf into centrifugal bins, to increase in the period of 1-$1\frac{1}{2}$ hours after lunch. Results during one day are shown in Table I. On other days the tendency was less marked or non-existent. However, one factor which influenced these trends was the variation in work load after lunch. On some days the early afternoon tended to be a peak period. In the case of the data presented in Table 1 the work load in the afternoon appeared to be high, as judged by the number of bins filled and removed. Thus the worker worked more continuously than usual at this period of the day though at a slower pace.

TABLE I

Samples of Cycle Times on Swarf Shovelling

No. of frames (at 2 per sec.)	Frequency distribution of samples	
	A.M.	P.M. (first $1\frac{1}{2}$ hrs of work)
15+		1
15		2
14		2
13		12
12	4	2
11	7	2
10	16	3
9	3	2
8	8	-
7	9	-
6	-	1
5	3	-

The shovelling of cement was an operation of comparable heaviness. The shovellers would spend approximately a third of a Cycle lasting two or three minutes shovelling cement while during the remainder of the Cycle they would turn off the current to the vibrating table, level the surface of the moulds, knock in wood blocks, clear the table, remove stray cement on the floor and switch on the vibrating table again.

When the data were analysed no variation in Element times that could be linked with the time of day was observed on any of the operations although it was evident that on shovelling Element times were subject to considerable periodic fluctuations. Part of the explanation of Element fluctuations, however, was attributed to the effects of periodic load shedding. The change in voltage would produce variations in the vibration of the table so altering the rate of compaction of the cement in the moulds. When the vibrating rate fell there was a tendancy for the cement to be under-compacted. This made the extrication of the block from the mould more difficult. Thus a lack of balance was caused between operators and the shovellers would be limited by the speed of work of the next operator. Studies of Element times throughout the day thus indicated either no interesting variation in relation to time of day or that such variation as did occur was masked by the effects of external variables.

The management of the factory on the other hand claimed that because of periodic inspection and checks it had been possible to count the completed blocks at different times during the day - those times being 9 a.m., 9.45, 10.30, 11.30 and 1.00 p.m., 3.00, 4.30, 5.15 and 6.30. When the voltage was normal the limiting factor of the Cycle was the speed of shovelling cement into the moulds. According to figures supplied representing average counts over a period of time far exceeding that of our investigation the number of moulds filled between 1.50 and 3.00 p.m. appeared to be 24% lower than the rate of production over the rest of the day. While this might accord with our previous evidence on swarf shovelling suggesting that this is a period when heavy work is subject to a reduction in output the lack of supporting evidence necessitates caution. If reduction in output is occurring at this period this is probably because of increased stoppages since Element times do not show any significant trend. However, the evidence is not sufficiently strong to affirm or reject this hypothesis.

Variations in Element or Cycle times were not found in any of the other studies to show any significant pattern. Our general conclusions in the matter, then, are in line with those of Dr Dudley (5) who studied Element and Cycle times throughout the day on twenty operations of varying demands and heaviness as recorded in his thesis 'The Output Pattern in Repetitive Tasks'. Dudley found no tendency for Cycle or Element times to diminish towards the end of a work period, i.e. the morning or the afternoon. No differences appeared in this respect between light and heavy operations. Dudley's data were derived mainly from material collected by himself acting as a time study observer. It nevertheless accords with our own information obtained from automatic methods of recording with the qualification that on heavy work there may be a tendency in some cases for Element and Cycle times to lengthen during the early afternoon.

Another aspect of performance now needs to be considered. This relates to the amount of time effectively taken in rest or relaxation from work.

Work Periods and Rest Periods

On many operations rest periods are taken only at the expense of earnings. Usually there is some minimum time in a factory which is allocated for the morning and afternoon tea break. However, on heavy work subject to incentive bonus payments it is often possible for workers to arrange their own breaks. The hours of actual work on the jobs studied above did not show any variations from the hours of actual work for the other operations in the same factory, except in the case of the two operations subject to heat stress, i.e. hand-rolling and hand-drawing.

On hand-rolling the men worked in eight hour shifts. The most arduous job was the rolling of the billet (weighing approximately 107 lbs) immediately as it left the furnace. Under intense radiant heat stress the billet was handled by two men. The man nearer the furnace would take out the billet with his tongs and then toss it to and fro between the rollers to his mate standing the other side. The billet would be rolled continuously for 45-50 seconds before it would be passed on to the next process and another taken out of the furnace. While the billets were fairly heavy the men handled them in such a way as never to take the full weight of the billet except in unloading from the furnace. The pulse count during work became stabilised around 120. The work was not therefore very heavy but it was exceedingly hot. All the men were paid on a group output or tonnage bonus. Owing to the arduous nature of the work the periods of working and of rest breaks within the shift were left to the men themselves but they were paid only for what they did. Typically it would appear that they would work for one hour and rest for a quarter of an hour or more according to the number of billets handled in the batch. A typical example taken from one of the periods of observation is shown in Table II.

TABLE II

Distribution of Work Periods on Hand-rolling
2 p.m. to 10 p.m. shift.

No. of Billets in Order	No. of Billets in Batch	Approximate Rolling.		Rest	
		Start	Finish	Start	Finish
138	46	2.15	3.15	3.15	3.30
	46	3.30	4.30	4.30	4.45
	46	4.45	5.45	5.45	6.15
108	54	6.25	7.25	7.25	7.40
	54	7.40	8.40	8.40	9.00
36	36	9.00	9.50		

The men would therefore take about two hours in the shift for personal relaxation or in other words would work for about six hours during the day.

A rather similar net effect was apparent with the hand-drawing of bricks. The men were paid according to the number of bricks drawn by the team and the hours of working were left to a large extent to the men themselves. In practice all teams worked during the mornings only, usually from about 5.30 a.m. to 12.30 p.m. They took a meal (breakfast) break from 8.30 to 9.00 a.m. and a ten minute break for a drink or cigarette usually between 10.30 and 10.40 a.m. and some teams took a second ten minute break.

In all then the hand-drawers worked on average little more than 6 hours a day. But while the several teams would vary the length of their working day to suit themselves, the high output teams would start earlier than the others but would never work on into the afternoon. It is tempting then to bear in mind our previous hypothesis of the reduced efficiency of workers on heavy manual work after lunch when considering the arrangement of the work by the men so as to avoid working after their meal.

When men are working under incentive conditions reduced work periods do not always reflect the need for rest, for reduction in work may be due to deliberate restriction of output. In the case of our own particular studies, however, conversations with the men and management discounted this as being a factor at all. If this is so we may draw the conclusion that at least in these cases the reduced hours actually worked by operators under incentive conditions gave a more sensitive indication of fatigue than our study of pulse counts or of variation in Element and Cycle times. But it is questionable whether the demands on energy expenditure in industrial work are of sufficient count, except in a very few cases, to enable the metabolic cost to be a major consideration and so to allow sufficient scope for the application of techniques of measuring energy expenditure which have been developed for maximal or submaximal energy expenditure under laboratory conditions. Some of our heavy shovelling operations entailed pulse counts of not more than 120 per minute, because the heavier parts of the task were always interspersed with light parts. Moreover much work is strenuous without involving high energy demands. For example, charger driving, see Figures 6 and 7, requires a charger to traverse and rotate in front of and alongside a furnace as a bin containing iron ore is picked up and emptied into the furnace and put down again in a 60 second cycle. The bin is picked up by the movement of the ram rod into a slot on the bin. This movement is dependent on a control which operates without any form of mechanical or power assistance. When the driver moves it forward it requires all his force and sometimes he finds it almost impossible to move while seated. The whole charger is subject to intense vibration largely owing to the small lumps or granules of anthracite which lie in the charger rails. Many of the charger drivers suffer from piles. They are also subject to intense heat during part of the cycle. The charger drivers at the time of investigation only worked for 50% of the day and refused during their inactive period to carry out crane driving on the grounds that charger driving was so fatiguing that they did not feel like other work afterwards. They were willing to submit themselves to the test of the M.P.I. Pulse Counter. Their pulse counts, however, averaged only about 90 beats per mean and never exceeded 100.

The example of the charger driver highlights one of our problems. This is that while many attempts which have been made by applied physiologists over the past thirty years to discover some measurable criterion of fatigue, of which lactic acid concentration in the blood or 17-Ketosteroid excretion in the urine are other well-known examples, these indices have always proved of very limited application or reliability.

Criterion of fatigue of an objective or phsiological character must always be limited by the fact that there are a large number of types of fatigue and ways in which fatigue can be manifested. Very appositely Brouha has referred to the problem as 'Les fatigues'. On the other hand the index of rest periods actually taken by operators at the expense of earnings has a certain universality of application for effective rest periods will reflect fatigue whatever the nature or character of the fatigue, although we must take good care to establish that these effective rest periods have not come about for other reasons. One of the simplest techniques may thus prove one of the most useful.

Further Studies into the taking of Additional Rest Breaks in Work

In our second series of investigations we have been concerned with the demands of operations which are subject to diminished hours of working or where rest breaks effectively taken are larger than the normal. The method has been

1. to seek out such operations in large industrial firms where there are many varied types of work,

2. to follow up such cases as have been reported elsewhere.

It soon became apparent during the early stages of these investigations that few heavy or moderately heavy operations entailed the taking of rest breaks greater than the customary standard in the factories concerned. Indeed it was a frequent complaint that the men did not take their C.R. although the management would often encourage them to do so.

Where rest breaks larger than normal are taken it is common to find that the work cannot be considered heavy at all. Rather the demands appear to be more on the mental and perceptual than on the motor side. Thus in our first case, which comes from a large firm manufacturing bearings, the only operation where additional rest breaks were regularly taken was roller and ball inspection (see Table III). The effective C.R. taken by inspectors was twice as great as that taken by other workers.

TABLE III

Working Periods on Roller and Ball Inspection

Work	Break
7.30 - 9.00	9.00 - 9.15
9.15 - 10.45	10.45 - 11.00
11.00 - 12.00	12.00 -[x] 1.00 p.m.
1.00 - 2.15 p.m.	2.15 - 2.30
2.30 - 3.45	3.45 - 4.00
4.00 - 5.15	

[x] Lunch

Longer rest breaks also occurred on two other inspection operations although these inspectors were not working under incentive. Nevertheless the internal evidence suggested that the formal or recognised nature of these rest breaks was in fact due to the fatiguing nature of the task.

The first of these operations was the viewing of radiographs in a firm associated with the aircraft industry which specialised in light alloy castings (see Figure 8). Each radiograph was held up in front of a screen emitting a strong diffused light. Shutters lateral and perpendicular were pulled to cut out light which would otherwise dazzle the viewer. The viewer would then examine the radiograph to detect small fractures and a host of other defects. It was very important that faulty castings should not be sent out by the factory.

Viewers chose to work for short periods of about ten minutes to one quarter of an hour and then to alternate their viewing with the physical examination of the casting itself, with clerical work and with other duties which included taking up the matter of faulty castings with those responsible. Such alternation of work, however, was not always possible and often viewers would be faced with a large quantity of work that required urgent attention as the castings were due for despatch. But continuous viewing could not be carried out for periods longer than 20 minutes to half an hour without the viewer feeling that the effects of fatigue were such as to impair his judgment. The most experienced viewer, however, could continue for about an hour before such effects were felt. If there was no ancillary work to be performed the viewer would take a rest period of about ten minutes before continuing.

An operation of a similar character was dust counting (see Figure 9). Dust counting is carried out in every area of the National Coal Board. Dust samples are collected at various points in the roadway of every pit and the sample is analysed as a means of protecting the miner from the hazards of pneumoconiosis. Dust counting requires the counting of the number of microns. The job is not difficult but demands continuous patience and concentration. The situation in which dust counting is carried out continuously throughout a day is avoided in most areas. Where continuous dust counting is carried out, however, a rest period of about ten minutes is allowed every hour. In other cases, however, where dust counting is intermittent and carried out with other duties no formal rest breaks are taken. In order to ascertain on this type of work the possible influences of fatigue, an experiment is now being conducted in cooperation with the East Midlands Division whereby in each of the six areas of the Division a log is being kept of the dust counters work. This will make it possible to check given slides (by their number) and to assess the influence of fatigue on accuracy according to (a) time of day, and (b) number of slides previously viewed. These results will be reported in due course.

It is worth noting that our hypothesis of the importance of the influence of fatigue on this type of work has been supported by recent evidence from an investigation into dust counting in South Africa (1). In an experiment in which the time taken to view each slide and the interval between each was controlled results indicated that an interval of not less than two minutes should be allowed between successive counts and not more than 18 counts should be made in one counting session.

On another attention demanding operation, a ten minute rest period every hour has been instituted. This applies to relay adjusting in a firm manufacturing telegraphic equipment. On this operation women adjust the springs of a relay so that each pair makes and breaks together and in the right order. A very careful touch is required for it is very easy to overcorrect and to cause one spring to become misaligned while aligning another. The job requires continuous attention and concentration. The ten minute break in every hour has now been introduced with success into several factories. An example of the effect of this experiment is shown in Figure 10 for one factory employing 56 relay adjustors. The workers, all of whom were on piece work, were able to earn more money per hour under the new conditions. While it appears that there may have been some 'Hawthorne Effect' to account for the fairly sharp rise in productivity after the introduction of the experiment it is nonetheless noteworthy that 30 weeks after the commencement of the experiment productivity is still slightly higher from 50 minutes work in the hour than under the previous conditions.

Another example of an operation making high demands on attention which was subject to additional rest periods was the punching of Hollerith cards in a factory which was concerned with the manufacture of batteries. The punch card operators received a continuous flow of records from which they would punch on a keyboard an equivalent card for use in the Hollerith machines. The operators could make mistakes in several ways, either in misreading the records, in punching the wrong numbers in the right place, or the right numbers in the wrong place. The work was subject to a sample recheck but even so mistakes could lead to serious consequences. The attention demands of the work were thus very high and these were accentuated by the fact that the work was carried out at high tempo. An obligatory rest period operated of five minutes in every hour additional to the morning and afternoon tea break and while there were no records whereby to judge its effectiveness, it was claimed by management to have led to more accurate work.

Where rest periods are not given for work demanding continuous concentration and attention there is evidence that the quality of the work suffers. An example of such a case is that of glass inspection on a continuous conveyor line. All the glass in this factory was bought as perfect and was then subject to annealing and further processing.

If the glass were to crack because of some impurity within it, such as a stone, there could be a total loss on the sheet without any possibility of reclaiming from the supplier. On the other hand if a faulty sheet was detected at the beginning of the process it would be replaced by a perfect one. All the faults that the inspectors had to search for were extremely small for the glass had already been inspected by the inspectors of the supplier but if only a few faults could be found an hour the job could be regarded as an economic proposition.

It seems reasonable to suppose that with only very small faults occurring on intermittent occasions efficiency on glass inspection would be low. There was, however, no objective means of assessing efficiency. However, it seemed that the number of plates thrown out per hour would, if a sufficiently large sample were taken, fluctuate according to hour of working if fatigue was an important influence on the operation.

In Figure 10 it will be seen that on both shifts there is a tendency for number of faults found (i.e. efficiency) to follow the same pattern. After the break both shifts show a steady decline. The consistency of this decline on both shifts strongly suggest that the reduction in faults found by inspectors can be attributed to fatigue. We cannot attribute it to any change in work load, for the sheets moved by continuously at a fixed rate on a conveyor belt. Moreover, as all the plates were withdrawn from a store with a time lag between this withdrawal and their reception from the supplier there was no apparent way in which glass faults could vary in their frequency according to hour of day other than through variations in the efficiency of the inspectors.

The small number of faults found in the first hour of the shift may be due to some extent to time lost in starting up. Thereafter, however, efficiency remains fairly constant reaching its peak in the period following the break. The actual break is officially of 30 minutes duration but from the information supplied by the time study department the conveyor generally remains idle for about 40 minutes. Whether we correct for 30 or 40 minutes it is clear that the break is followed by the period of highest efficiency. Thereafter on both shifts there is a progressive but steady decline.

We may conclude this section by referring to an improved method for measuring efficiency on inspection operations, for as we have seen, human performance seems especially susceptible to fatigue on this type of work. This method, which is proving to have a scope considerably beyond the confines of our present research problem, is described in Appendix I together with some preliminary results that have been obtained in the use of the method.

DISCUSSIONS AND CONCLUSIONS

The significance of the results of our investigation cannot be realised until some precise comparisons are made with the ways in which C.R. allowances are awarded in general practice. In order that the relative importance of one factor against another may be seen under existing systems we have summarised information taken from three firms of industrial consultants (1-3) and five of the largest manufacturing concerns in the United Kingdom (A-E) and one (F) from an organisation serving a particular industry. The information collected applies only to allowances that are awarded for different factors on an additive basis. The arrangement of the information has been such as to show the recommended values or the central value of a recommended range. This affords a useful comparison because there is a well-known tendency for observers to use the central values of a range of stimuli where some measure of subjective judgment is involved. We may suppose that this tendency applies also to the application of C.R. values. Moreover comparison of these central values (or in some cases precise values) gives an indication of the relative emphasis of one factory against another in the construction of these schemes. In certain cases as with the application of effort the range may be divided into precisely defined steps. Thus in the case of effort we have used a precise example, i.e. the application of force of 50 lbs, to show the values that would be derived under the various systems.

Inspection of the Table suggests three conclusions.

1. The values awarded between different firms for the same factors and the relative order of the various factors vary considerably, the more so when we realise that there has been some obvious borrowing of definitions and values between the different firms.

2. Factors affecting the physical environment and the physical demands of the job tend to receive allowances that are relatively large in comparison with the factor of Concentration and Attention which our research results indicate as being of special, perhaps of prime, importance in requiring rest periods to relieve fatigue. Concentration and Attention are one of the factors receiving least C.R. Allowance.

3. Some Factors that commonly qualify for C.R. Allowances give no evidence of fatigue on any of the established criteria.

In expansion of the last point it would appear that many factors that crept into the C.R. Allowance tables deserve to be considered critically. In this category we would place in particular Environment/Work Area which includes such factors as 'the presence of dirt' which hardly appears to have any connection with fatigue at all.

THE VARIATIONS IN C.R. ALLOWANCES AS AWARDED BY VARIOUS INDUSTRIAL FIRMS AND ORGANISATIONS

Actual Allowance or Central Value of Range of Allowances awarded for Compensating Rest as a Percentage of Normalised Time.

Factor	Industrial Consultants			Firms					
	1	2	3	A	B	C	D	E	F
Basic/Personal Needs Allowance	8	2	3	2.5	10	6	2.5	3	8
Energy Effort	6	10	22.5	18	26	75	15.75	4	6
Exercise Force of 50 lb.	42	15	40	27.5	33	40	20.5	(11)	50
Posture	5)	5)	18	5	6)	12.5	5	1.5	5)
Restraint in Motions/Position/Foot Position	)	)	11	7.5	)	-	7.5	3	)
Temperature	7.5	5	⌿	75	5	25	50	1.5	7.5
Atmosphere/Ventilation	7.5	4	-	17.5	2	2.5	17.5	1.5	7.5
Environment/Work Area	7.5	7.5	-	3.0	2	-	5	1.5	7.5
Noise	7.5	1	-	3.5	5	1.0	2.5	1.5	7.5
Clothing	-	7.5	-	10	5	2.5	8.5	-	-
Monotony/Cycle Length	2.5	5	⌿	2.5	-	.75	1.5	-	1.5
Complexity	-	-	-	-	-	-	-	2	-
Loneliness	-	5	-	1.5	-	-	-	-	-
Eyestrain/Bad Light	7.5	5	3	5	7	4	3.5	-	-
Concentration/Attention	3.5	3.5	4.5	5	4	2.5	3.5	1.5	3.5

⌿ Not possible to represent. ( ) Not given specifically.

The adjoining table shows that the present of noise frequently qualifies an operation for a C.R. Allowance. But while operators become in a sense fatigued by noise this fatigue is adaptive rather than maladaptive, for habituation to noise enables the operator to carry out his work without a sense of disturbance, although noise is a factor that may discourage a newcomer from taking up the work.

The wearing of special clothing is another item concerning which doubts may be expressed. It is true that wearing gloves, for example, may interfere with work. It may lower effectiveness but effectiveness is covered during rating. Gloves have to be put on and taken off but this is merely ancillary work, duly covered in work measurement. Fatigue from wearing gloves is difficult to envisage except under conditions of high heat stress.

Atmosphere/Ventilation are known from the studies of the Industrial Health Research Board to affect individual efficiency but the category has been enlarged to cover conditions that while unpleasant are unlikely to exercise a detrimental effect on normal working. For example, the 'presence of foetid odours' is subject to the same type of adaptive fatigue (habituation) that we found in the case of noise, enabling the worker after the elapse of a period of time to work with comparative unawareness of its presence.

Mental fatigue is known in certain cases to exercise a detrimental effect on output and efficiency and it is presumably this that is referred to in allowances awarded under the heading of Loneliness, Monotony and Short Cycle work. But while these factors sometimes correlate with Mental Fatigue the correlation should not be assumed. For example loneliness may make work less socially satisfying but it appears to render it less subject to social interruption. Conversely the tendency for personal delays to be high where work is social (and subject to interruption on that account) has already been well illustrated by Williams (16). It is the variations in these personal delays on different classes of work that C.R. Allowances endeavour to cover.

Cox (14) and others have already shown that monotonous and short cycle repetitive work are not necessarily disliked by operators at all, or the subject of boredom so long as work makes only low demands on attention. Indeed such work is frequently preferred to work which is less monotonous but entails more responsibility and attention and there is usually no shortage of labour for such work although many individuals of higher intelligence and education dislike it intensely. In our own investigations we found that a group of women polishing bearing rings, with a time cycle of 3-4 seconds, often worked through part of their rest break. They appeared to converse continuously, being seated around a common table, and their conversations did not restrict the quality or quantity of their output.

Eyestrain, Concentration and Complexity appear as separate though largely overlapping factors. Thus for work requiring keen vision C.R. Allowances may be awarded under two headings, Eyestrain and Concentration. But unless concentration is required it is very seldom that the operator will be subject to eyestrain. Concentration/Attention may therefore be doubly rewarded. Allowances could be awarded in general rather easily under this heading for a great deal of work may be described as requiring close attention. But the question is of course how close is close attention. In the operations placing high demands on attention and where evidence of fatigue has been found it would seem that the demands on attention and concentration were such that

1. the level of attention of concentration was affected very little by the acquisition of skill,

and 2. the level of attention and concentration was such as to make conversation impossible during work without restricting the quality or quantity of output.

It is clear from our studies in industry when high demands are made on attention and concentration the evidence of the influence of fatigue is fairly marked. Moreover, experimental evidence lends considerable support to this view. Carmichael & Dearborn (3) report deterioration in performance in the reading of microfilm after two hours, Siddall & Anderson (13) report deterioration on a tracking task after 30 minutes and Singleton (15) reports deterioration on a simple task involving the continuous manipulation of a control in a four choice situation. After two minutes, a progressive decline was found to apply to that part of the task entailing choice (time at choice points) rather than to speed of movement (movement times per se). Rapid deteriorations in performance have been reported by Mackworth (7) and Broadbent (2) after relatively short periods of working on tasks involving prolonged vigilance, both visual and auditory, while Pepler (9, 10, 11) in a series of studies of the influence of heat stress on performance has shown that impairment is especially marked on tasks making high perceptual and mental demands which are linked with some form of speed stress (i.e. involving continuity in concentration and attention).

Our conclusion that operations making high demands on concentration and attention are especially liable to the influences of fatigue seems well supported. Yet, as we have seen, attention/concentration receive low C.R. Allowances. We must presume that if attention/concentration could be gauged more definitely larger allowances could be awarded. At present, however, there are obvious dangers in recommending a range with a high ceiling, for observers can easily overestimate the extent to which work makes demands on concentration. During our investigations much work has been encountered that appeared to involve a high degree of concentration and close vision (which it undoubtedly did for beginners and less experienced operators), but skilled workers would often give the task only intermittent attention and could afford the luxury of glances round the room or conversations with their neighbours without interuption to their work.

This suggests that on many tasks the demands of attention and concentration are high (and fatigue an important factor) only in initial stages but that later when the skill has been mastered performance is less subject to the influences of fatigue. This is supported by evidence drawn from the field of operator training. Advanced methods developed by industrial training specialists demand the early acquisition of the required speed for only a few cycles and for sometimes only a part of the cycle. The attainment of the eventual daily production output is reached only gradually by an extension of what are termed 'stamina runs' and the non-attainment of the daily output standard when standard cycle times have already been attained is recognised as an inevitable occurence and is attributed to the influences of fatigue during the learning process (12).

On many operations then mental and perceptual fatigue applies largely to the beginner. But it is clear that high C.R. Allowances cannot be recommended for work where fatigue assumes only a transitory significance.

Extra C.R. Allowances then for work involving mental and perceptual fatigue are not easy to apply, for it is essential to ascertain how far fatigue may be mitigated or annulled by the acquisition of skill. Yet it is precisely this type of work, which is most difficult to assess, that will in the main require these extra allowances. It is true that factors other than those of attention and concentration have been found by previous studies to merit special consideration. The early studies of the Industrial Fatigue Research Board revealed that fatigue produced significant effects in conditions where extremely long hours were worked, where very heavy work was performed or where bad thermal and atmospheric conditions prevailed. But under the improved conditions of modern industry such work is becoming increasingly rare with the exception of thermal stress which still remains as a problem of no less importance. However, perceptual and mental fatigue far from being in the wane appear to be of increasing concern for it is man's senses, judgment and skill which appear in greatest demand in modern industry.

Some Considerations Arising from our Research into Current Methods of Applying C.R. Allowances

If it is true that the many factors which normally qualify for C.R. Allowances above the basic allowance produce no evident effect on performance that suggests that fatigue is operating, little can be said to justify these extra allowances. On the other hand it cannot be doubted that men whose jobs require periodic effort and who work in unpleasant environments may reasonably demand more in payment than those whose work is light and who work in ideal surroundings. But if questions of extra payment are involved it is important that such questions should be recognised for what they are and that C.R. Allowances should not be used as a disguise for extra payments.

At first sight it may seem immaterial whether such extra payment is made possible in the form of C.R. Allowances (through operators on piecework working through the period allocated for C.R.) or in the form of policy allowances or in higher rates for the job resulting from factors which hitherto had qualified for additional C.R. Allowances now meriting consideration under job evaluation. Nevertheless there are decided disadvantages in the use of C.R. Allowances as a means of increasing the rate for the job.

Our objections to the current approach of applying C.R.Allowances may be summarised as follows.

1. The C.R. Allowances, being incorporated into the work unit values or standard minutes allowed for the job may result in unrealistic or loose values being applied in production planning. The following is an example. Workers in Factory A load swarf and scrap into a bin which feeds a furnace. Subsequent operations depend on the output of the furnace and must be manned accordingly. The output of the furnace may be calculated from filling time plus process time. The filling times depend on the performance of the loaders who work at approximately a standard performance (i.e. at an 80). However, owing to the heat stress, the energy requirements of the job and the adverse working conditions, the loaders are given a C.R. Allowance of 50%. After the loading lasting half an hour has been finished, however, the men carry out miscellaneous duties (unmeasured work for which they are paid at time rates) until the cycle recommences. During the slack period the men take effectively the rest which their work entails, while during the filling they work without relaxation. The furnace is therefore loaded in practice in two-thirds of the time calculated. There is then a tendency for some dislocation to occur in the later operations in a failure to keep pace with the output of the furnace. Like most problems, the problem is eventually solved empirically but it appears to have only arisen in the first place because of the misconception concerning C.R. Allowances.

2. C.R. Allowances very often make it easier to 'sell the time for the job' on the shop floor. The actual time allowed for a given number of units under a new method often may not mean very much to an operator but the rest allowance will always mean something to him and an allowance of 15 or 20% for rest may sound very generous. It is very apparent that many time study engineers and industrial consultants have used tight times in combination with loose allowances. However, apart from the moral disadvantage of this deception, such a policy appears to exercise a long-term disadvantage.

The improvements which are being made progressively to jobs in industry and to working conditions frequently result in the cutting of C.R. Allowances so that a method change sometimes meets an adverse reception and the worker complains that he is worse off. On the other hand where blanket C.R. Allowances are applied the improvement of the working conditions and the removal of the arduous parts of a job through the work of the Work Study Officer are welcomed by workers on the shop floor when they see that some benefit may be derived from method and technological changes.

3. The tendency to use allowances to cover up other things can exercise a detrimental effect on the training and outlook of the Work Study Officer. Successful Work Study depends on the ability to see a problem as it really is and it is important that the techniques of the Work Study Officer should reflect this outlook.

4. Complicated systems of C.R. Allowances applying to large numbers of factors and operated on an elemental basis involve considerable paper work and are time consuming. They can introduce a measure of bureaucracy into Work Study of which the following provides a useful example. This extract is taken from a scheme used by a firm of industrial consultants.

<u>Contents of Tables and Sequences of Calculations</u>

Table 1:	Combination of and	Effort Exerted (0-130 lbs) Position of Body while exerting effort, (sitting-standing-reaching-lying on back)
		PLUS
Table 2:	Combination of and	Nature of Foothold (sitting-uneven floor-climbing) Liberty of movement
		PLUS
Table 3:		Degree of Eyestrain (labourer-watchmaker)
		PLUS
Table 4:	Combination of and	Attention (none-much) Thinking (none-much)

Take sub-total and multiply by

Table 5: Factor related to

Length of Cycle (very short-very long)
(inclusive of enforced waiting time)

Multiply by

Table 6: Factor related to Ratio:

$$\frac{\text{Sum of times of 'heavy' elements (Table 1)}}{\text{Cycle Time}}$$

Multiply by

Table 7: Factor related to combination of:

Temperature
Humidity

Table 8: The total of these percentage allowances is obtained and against it is offset the values for 'proportions of enforced waiting time' in the cycle given by Table 8.

The result of this subtraction must never be less than the sum of Personal Allowances and recognised rest pauses. If necessary, some restoration must be made to satisfy this last consideration.

Recommendations

In conclusion our recommendations may be summarised as suggesting the following:

1. That blanket or standard rest allowances should be used in most cases, bearing in mind that to a large extent they reflect personal and social needs.

2. That extra fatigue allowances should be applied in certain cases where it is believed or has been ascertained that operators take effectively more relaxation than on other work and where this relaxation can be regarded as legitimately reflecting the additional fatigue that the work entails. For large concerns it may be suggested that key operations of this type should be studied and that from the information that is yielded 'bench marks' or reference points should be established for the application of extra fatigue allowances in other cases.

3. That operations making high demands on attention and concentration should merit special consideration.

4. That from the outcome of our investigations into the most extreme operations the basic allowance plus the extra fatigue allowance should have a theoretical maximum not exceeding 30-35 per cent.

5. That factors which would normally qualify for C.R. Allowances should, where operations receive a standard rest allowance, be incorporated into a revised system of job evaluation.

Appendix I

Development of an Improved Technique for Measuring Efficiency on Inspection Work.

If it is true that operations making strong demands on attention and concentration are especially susceptible to fatigue it is imperative that for these types of operation improved methods of measuring human efficiency should be found. Such methods would at the same time enable improved control to be gained over this type of work. To this end a new technique has been developed which may be termed the controlled sample technique. This method entails the establishment of a test sample of items or products all of which contain known faults. These items are then mixed with the normal work which the operator inspects. We may not know the efficiency of the inspectors in inspecting the rest of the batch directly, but if we know their efficiency on the sample we may argue on statistical grounds that this efficiency will represent a true general index of efficiency, provided that the test items do not appear as part of an experiment and are indistinguishable from the other items except in respect of the faults that they contain. The problem is to develop a means whereby the test items can be reclaimed without their appearing to the inspector as having been marked.

This problem was first approached in relation to glass inspection. The attempt to build up a sample by use of radioactive isotopes failed, because either the half life of the tracers was too short to enable the sample to be retained for any practical length of time or greater length would have involved hazards to customers should any of the sample escape.

A method of marking a sample which could have a very widespread application is invisible ultra-violet dyes which will fluoresce when viewed under an ultra-violet lamp. We are now using this method to investigate the efficiency of inspectors concerned with the following products:

stockings (using a sample dyed in Fluorite C),

ampoules in the pharmaceutical industry (adding one gramme of Quinine Sulphate per ten litres of liquid)

and radio valves (after staining the micas with Eight-Hydroxy-Quinoline).

These methods have proved very effective. For example a tray of 50 valves requiring about half an hours work and containing a few test items can be checked in a few seconds under the ultra violet lamp. In the case of ampoules hours of work may be checked in a very short time for test items lying at the bottom of a tray, containing several hundred ampoules, fluoresce so strongly that they can be detected without difficulty. An illustration of three test ampoules containing critical faults together with controls is shown in Figures 12 and 13.

Other methods also have application for the detection of test samples. In the ball bearing industry balls and rollers are subject in the final inspection room to a mechanical inspection for size and to final viewing. By slightly varying the size of a test sample containing surface defects from the rest of a batch it was possible to reclaim the sample by mechanical size grading subsequent to viewing. In the first experiment the management selected 100 balls containing major faults which were 'obvious' and which 'the girls would have no difficulty in finding'. These were added to a batch of balls numbering about 26,000. The results are shown in Table IV. It will be seen that the first stage viewing is 63% efficient in the detection of major faults but that the second stage viewing (the final check to detect any strays missed by earlier viewing) is only 48% efficient. It is interesting to note that 3% of the sample is lost, which is an indication that losses occur in the normal course of handling.

TABLE IV

Fault	Analysis of faults on size $\frac{3}{8}$" - .0007" faulty balls (added to a batch of $\frac{3}{8}$" std. balls.)	Found in 1st visual inspection	Found in 2nd visual inspection	Found in grading machine	Total
Diameter Blacks and Flats	30	19	5	3	27
Cracked	20	14	3	3	20
Burst	20	11	3	6	20
Soft spots	20	11	3	6	20
Badly formed	10	8	2	-	10
	100	63	16	18	97

The controlled sample technique has met with considerable interest from industry and it is clear that the technique has applications for improvement in quality control and to the possible payment of quality bonuses.

Work in the use of the technique for experimental purposes began only recently but it is hoped that in a few months time sufficient information will have been obtained to ensure a far more accurate assessment of the influence of fatigue and other factors on individual efficiency in inspection work.

REFERENCES

1. Beadle, D.G. and Kerrick, J.G. (1955)
A Statistical Examination of the Performance of the Thermal Precipitator. J.Chem.,Metall. and Min.Soc.S.A., Dec, 1955.

2. Broadbent, D.E. (1950)
The Twenty Dials Test under Quiet Conditions. Med. Res. Council A.P.U. Rep. 130/50.

3. Carmichael, H. and Dearborn, W.F. (1948)
Reading and Visual Fatigue. Harrap, New York.

4. Cox, D. (1953)
Women's Attitude to Repetitive Work. Nat. Inst. Indust. Psychol. London.

5. Dudley, N.A. (1955)
The Output Pattern in Repetitive Tasks. Ph.D. dissertation deposited in B'ham Univ. Lib.

6. Lehmann, G. (1953)
Praktische Arbeitsphysiologie. Georg Thieme. Stuttgart.

7. Mackworth, N.H. (1956)
Work Design and Training for Future Industrial Skills. Paper Presented to the Institution of Production Engineers, 9th Feb., 1956.

8. Norbury, C.J. (1954)
The Application of Memo-motion to Industrial Operation. Coll. of Aero. Rep. No.86.

9. Pepler, R.D. (1953)
The Effect of Climatic Factors on the Performance of Skilled Tasks by Young European Men Living in the Tropics.
5. A Complex Mental Task with Varying Speed Stress. Med. Res. Council A.P.U. Rep. 196/53

10. Pepler, R.D. (1953) IBID.
6. A Task of Continuous Pointer Alignment at Two Levels of Incentive. Med. Res. Council A.P.U. Rep. 197/53.

11. Pepler, R.D. (1953) IBID.

7. A Complex Mental Task with Varying Speed Stress at Two Levels of Incentive. Med. Res. Council A.P.U. Rep. 198/53.

12. Seymour, W.D. (1954)

Industrial Training for Manual Operations. Pitman, London.

13. Siddall, G.J. and Anderson, D.M. (1955)

Fatigue during Prolonged Performance on a Simple Compensatory Tracking Task. Quart. J. Exp. Psychol. 7, 159-165.

14. Sills, E.C. (1954)

An Improved Pulse Counter. Coll. of Aero., Aircraft Elect. Sect. Note.

15. Singleton, W.T. (1953)

Deterioration of Performance on a Perceptual-Motor Task. In Floyd and Welford (Ed.), Symposium on Fatigue, H.K.Lewis, London, 163-172.

16. Williams, J.A.C. (1955)

Avoidable Delays among Women Workers on Light Work. Coll. of Aero. Note No.18.

17. Williams, J.A.C. (1955)

Heat Stress Rest Allowances in Time Study; a Rational Basis. Dept. Aircraft Econ. & Prod. Report No.CA/PE/4.

18. Williams, J.A.C. (1956)

Heat Stress Rest Allowances in Time Study; Further Considerations. Dept. Aircraft Econ. & Prod. Report No. CA/PE/5.

19. Williams, J.A.C. (1956)

Partial Derivates of Globe Temperatures and Belding & Hatch Heat Stress Index. Dept. Aircraft Econ. & Prod. Report No. CA/PE/6.

20. Williams, J.A.C. (1956)
Work Decrement with Increase of Heat Stress Factors. Dept. Aircraft Econ. & Prod. Report No. CA/PE/7.

21. Williams, J.A.C. (1956)
Method Study of Hot Working Conditions. Coll. of Aero. Note No.46.

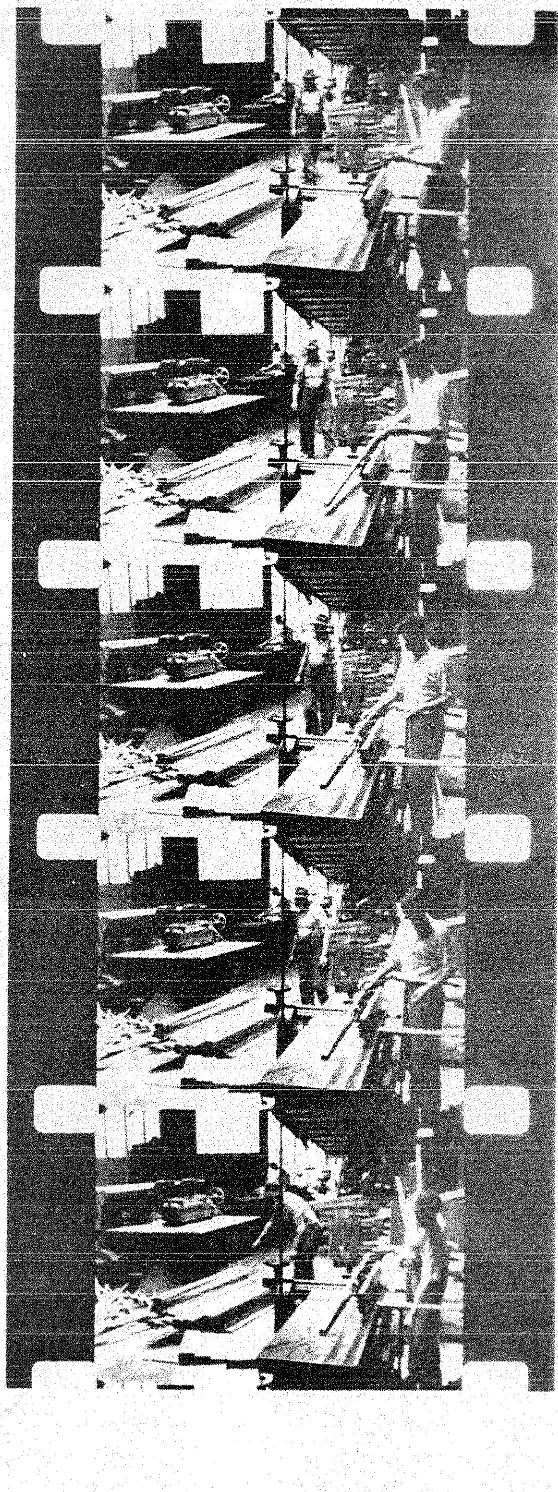

FIGURE 1. EXAMPLE OF THE USE OF THE CRANFIELD MEMO-MOTION CAMERA SHOWING THE WORK OF A WOOD-MACHINIST TAKEN AT TWO FRAMES PER SECOND.

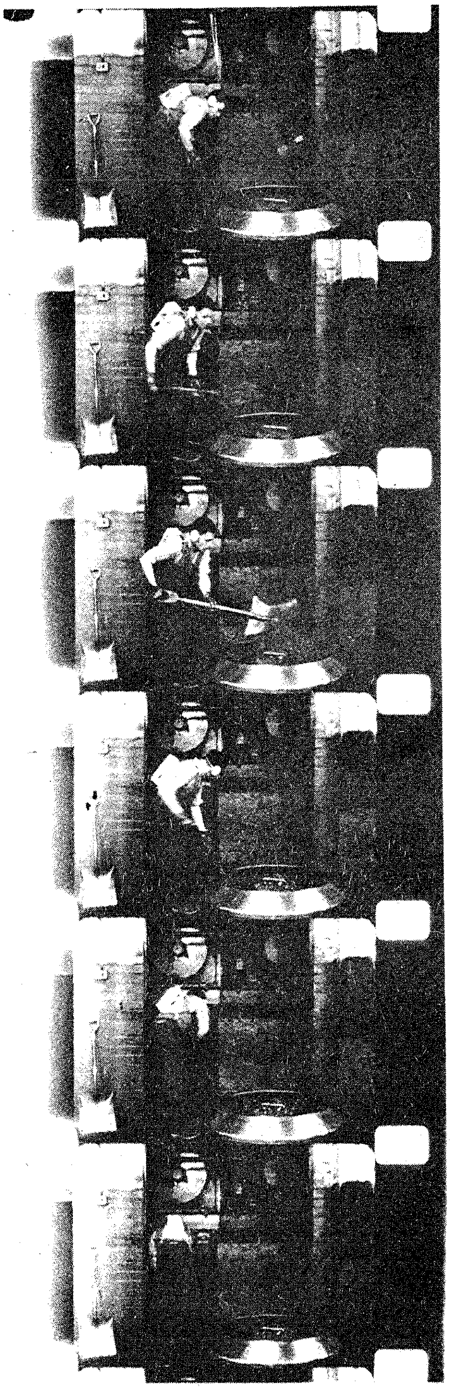

FIGURE 2.

USE OF THE M.P.I. PULSE COUNTER TO MEASURE THE METABOLIC COST OF SWARF SHOVELLING

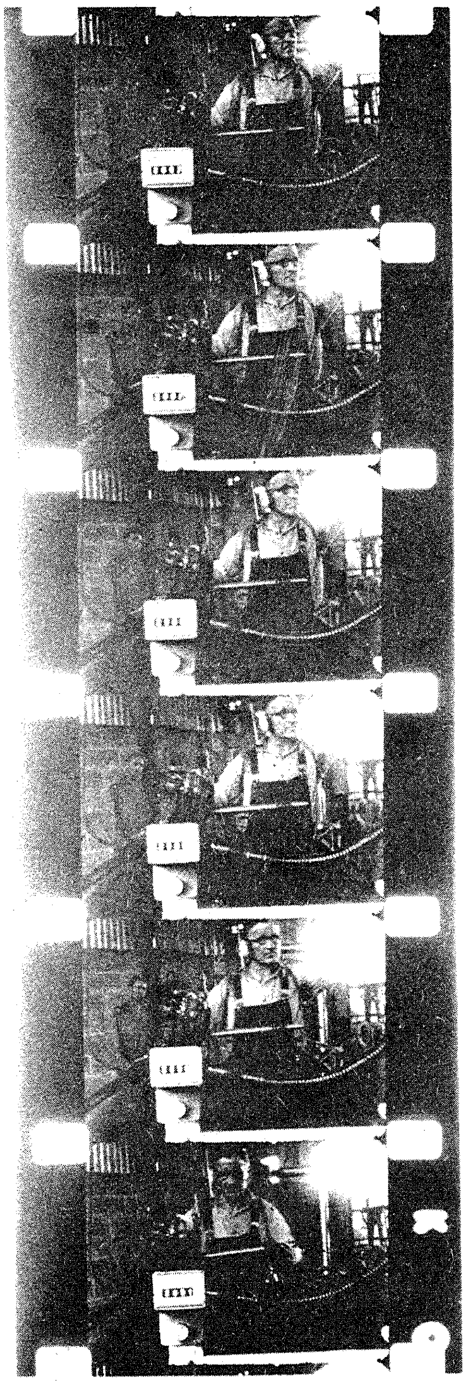

FIGURE 3.

THE RECORDING OF THE PULSE COUNT WITH THE ELEMENTS OF A CYCLE.

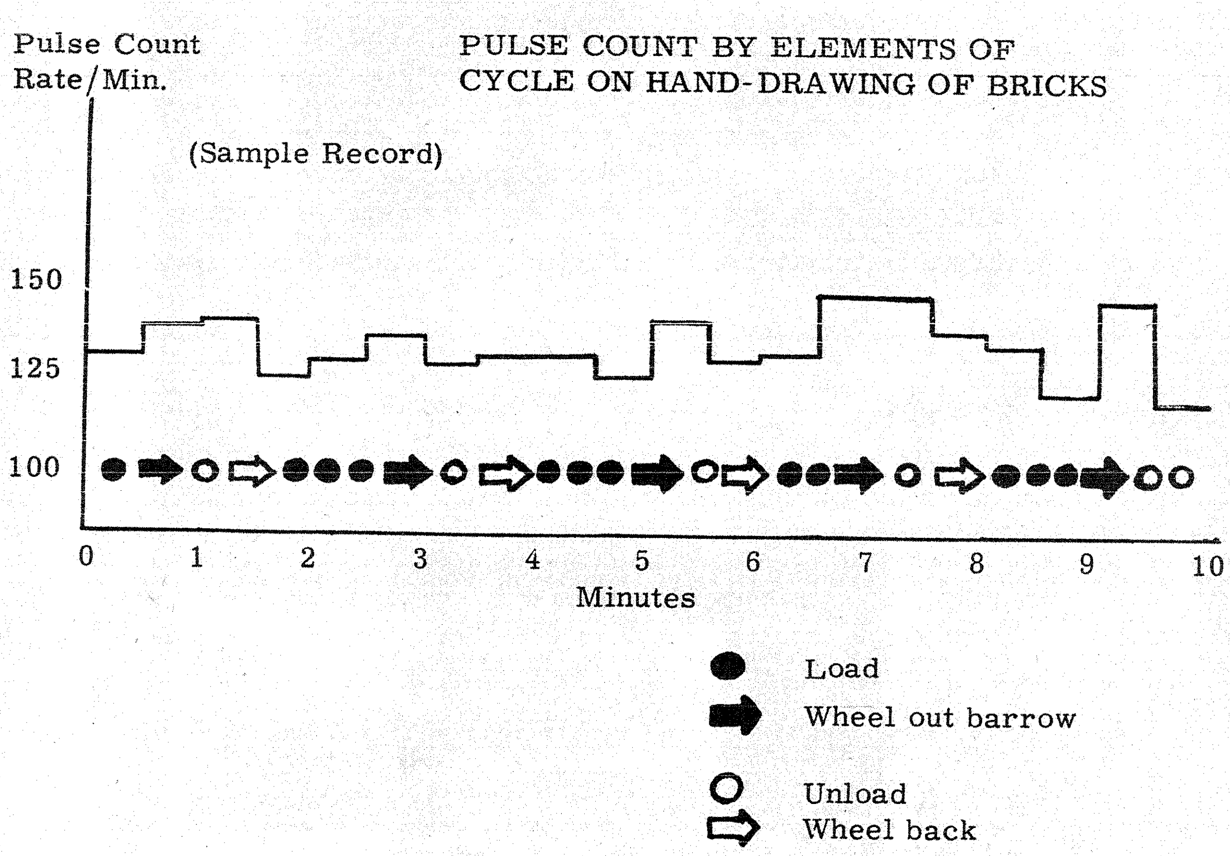

FIGURE 4. A SAMPLE RECORD SHOWING THE RELATIONSHIP BETWEEN THE ELEMENTS OF A CYCLE AND THE ENERGY COST.

In each cycle as the hand-drawer wheels out the barrow there is a rise in the pulse count. The removal of the barrow from the kiln is thus shown as the heaviest element of the job.

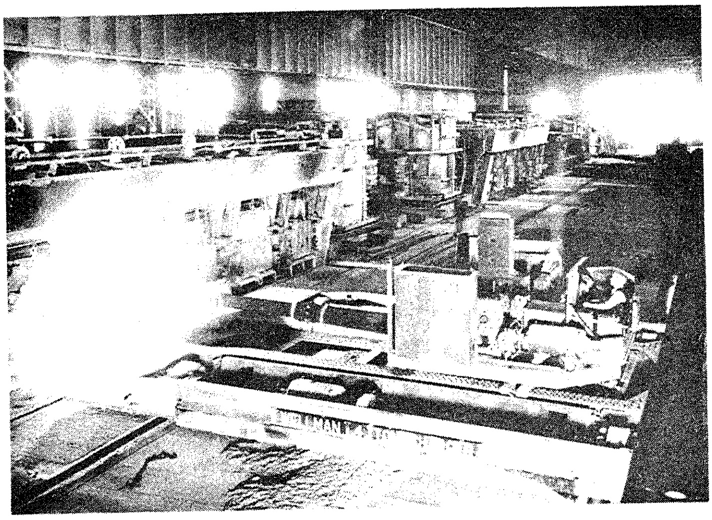

FIGURE 5. WORKING ENVIRONMENT OF THE CHARGER DRIVER

FIGURE 6. A CHARGER DRIVER OPERATING HIS CONTROLS
The work of a charger driver is strenuous in various ways but the energy cost is low.

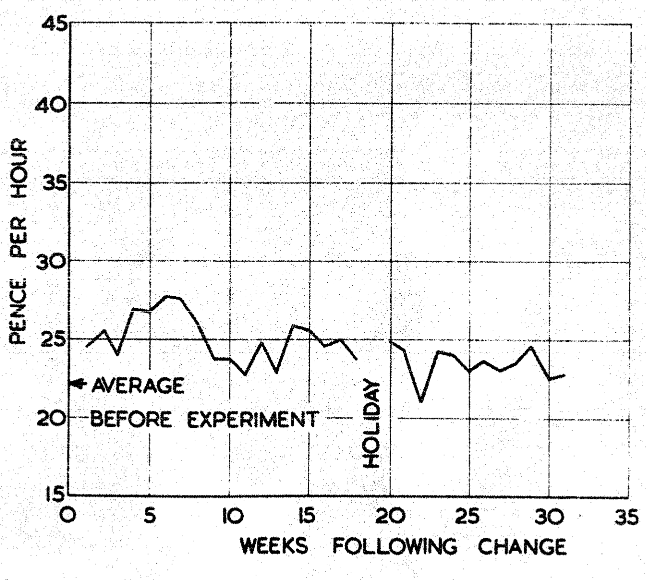

FIGURE 9. AVERAGE EARNINGS FOR RELAY ADJUSTORS (MEAN No. 56) FOLLOWING INTRODUCTION OF HOURLY TEN MINUTE REST PERIODS

With ten minute rest breaks every hour relay adjustors produce an output as great or greater than their previous average.

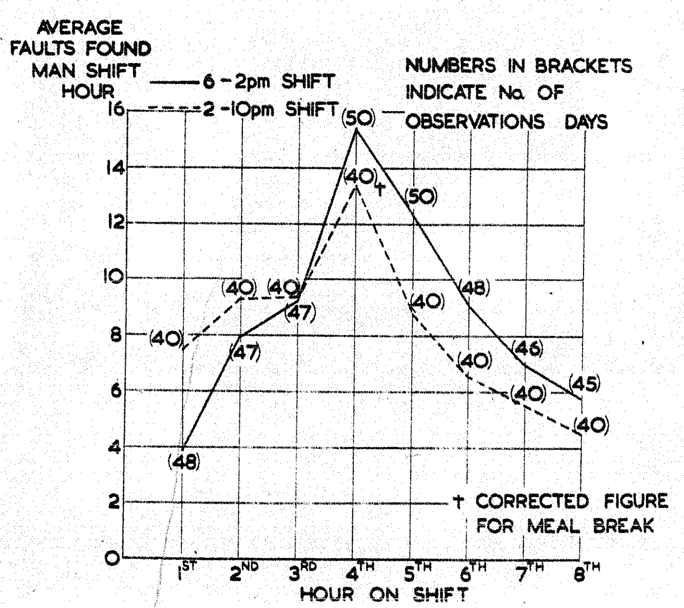

FIGURE 10. NUMBER OF FAULTS FOUND AS AN INDEX OF HOURLY EFFICIENCY IN GLASS INSPECTION

Glass inspectors reach their peak efficiency after their break but thereafter show progressive decline.

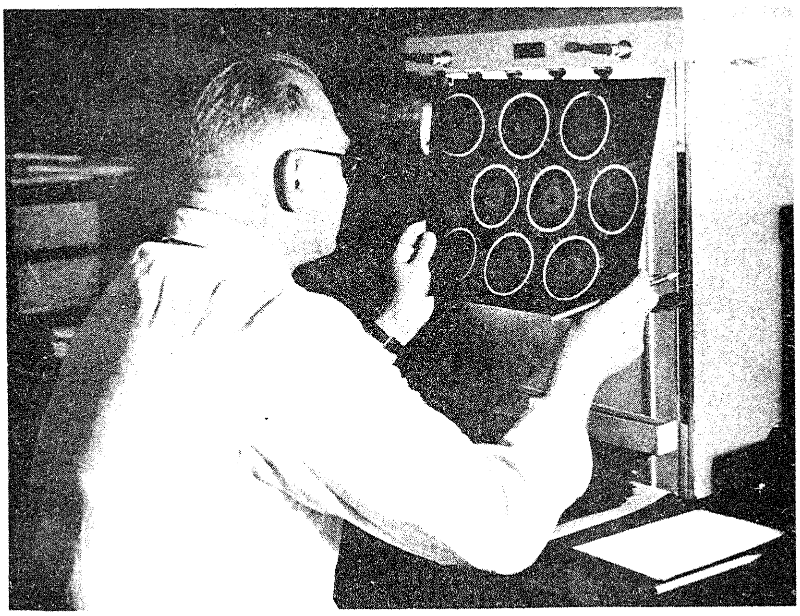

Figure 7. AN INSPECTOR VIEWING RADIOGRAPHS
The work of viewing radiographs entails rest breaks at more frequent intervals than other operations in the same factory.

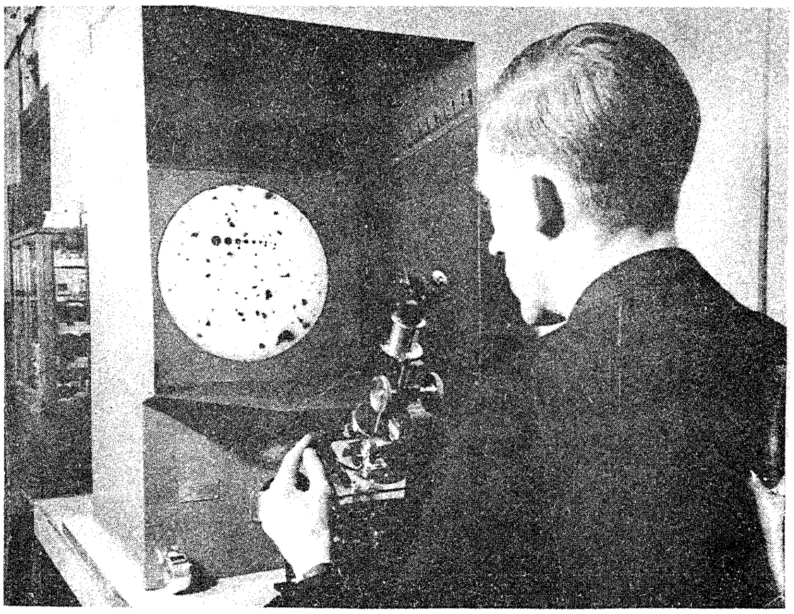

FIGURE 8. THE INSPECTION OF DUST SAMPLES
The performance of the dust counter is very variable but frequent rest periods during long spells of counting increase the accuracy of work.

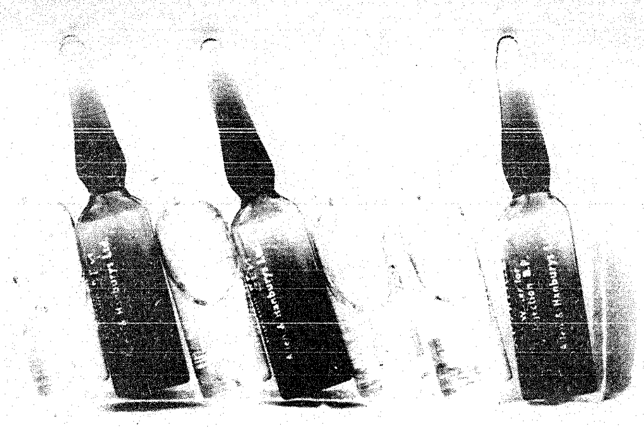

FIGURE 11. AMPOULES CONTAINING THE FLUORESCENT DYE AS SEEN WITH CONTROLS UNDER THE ULTRA-VIOLET LAMP

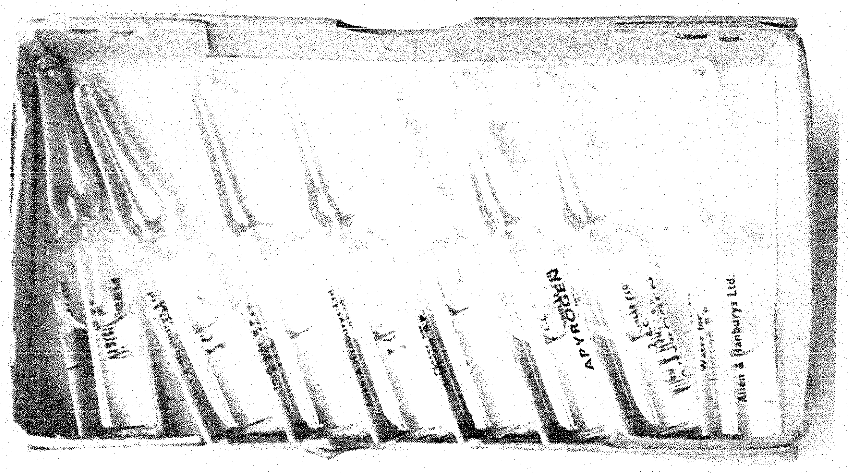

FIGURE 12. AMPOULES CONTAINING THE FLUORESCENT DYE AS SEEN UNDER NORMAL LIGHTING

Ampoules containing the fluorescent dye are indistinguishable from other ampoules under normal lighting. But under an ultra-violet lamp they are easily distinguished.