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# THE EFFECTS OF CONDITIONS OF ARTIFICIAL LIGHTING ON THE PERFORMANCE OF WORSTED WEAVERS

By H. C. Weston

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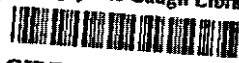
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REPORT No. 81

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OF ARTIFICIAL LIGHTING  
ON THE PERFORMANCE OF  
WORSTED WEAVERS

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HIS MAJESTY'S STATIONERY OFFICE

1938

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## PREFACE

The effects of conditions of lighting on the performance of industrial tasks has been observed incidentally in the course of a number of investigations made for the Board, and the results of these observations have been published in their series of reports. In 1926 there was published the first of a series of Joint Reports of the Industrial Health Research Board and the Illumination Research Committee of the Department of Scientific & Industrial Research. That report described the results of a particular investigation into the relation between illumination and performance in type-setting by hand.

The large part played by vision in the performance of almost every kind of work, and the obvious dependence of good vision on adequate illumination, points to lighting as one of the most important conditions of work within a factory. The experimental study of lighting under industrial conditions, however, presents difficulties no fewer than those which commonly attend similar studies of other environmental factors. The difficulties are chiefly those of finding or producing, in a factory, the controlled conditions of a laboratory experiment.

In the present investigation, which was made in a weaving shed where a night-shift was worked, one of these difficulties, namely the short and variable duration of artificial lighting during usual factory hours, was largely, although not entirely, overcome. The primary object was to test the value of a method of lighting looms which had been claimed to have given excellent results when tried in Germany. Confirmation of the German results has not been obtained, but the data presented suggest that a higher illumination than is customarily provided is necessary to secure the best performance in weaving certain kinds of cloth.

It must be admitted that, in view of the general variability in output recorded, far more data than it was found possible to obtain would be required to establish with certainty the conclusions arrived at. Nevertheless, both in respect of degree of illumination and method of lighting, the conclusions suggested by the present investigation and those drawn from the earlier type-setting experiments are mutually confirmatory. Though technically dissimilar, the work of the hand compositor and that of the worsted weaver largely consist of comparable visual tasks.

The Board therefore felt that the results of this investigation should be published, giving as they do some indication of what may be considered to be good lighting for a particular industrial process. In making this decision to publish, they have been supported by advice from the Committees on Vision and Statistics of the Medical Research Council and from the Illumination Research Committee of the Department of Scientific & Industrial Research. It seems to them, also, that the results gain particular current interest owing to the general clause in the new Factories Act requiring adequate and suitable lighting in factories.

THE EFFECTS OF CONDITIONS OF ARTIFICIAL  
LIGHTING ON THE PERFORMANCE OF WORSTED  
WEAVERS

By H. C. WESTON, M.J.Inst.E.

CONTENTS

PART I		<i>Page</i>
A. Introduction .. .. .	1	1
B. Method and Scope of Investigation .. .. .	1	1
C. Summary of Results .. .. .	2	2
D. Conclusions .. .. .	5	5
PART II		
A. Requirements of Loom Lighting .. .. .	6	6
B. Data obtained .. .. .	7	7
C. Illumination .. .. .	9	9
D. Discussion of Results .. .. .	9	9
<i>Appendix I</i>		
Note on the Comparison of Night Weavers' Output in different Experimental Lighting Periods, and on the Comparison of Night with corresponding Day Weavers' Output in the same periods .. .. .		24
<i>Appendix II</i>		
The Significance of Output Changes. Operations in weaving affected by Lighting. Probable Extent of Output Gain obtainable with Improved Lighting .. .. .		26

# THE EFFECTS OF CONDITIONS OF ARTIFICIAL LIGHTING ON THE PERFORMANCE OF WORSTED WEAVERS

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H. C. WESTON

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## PART I

### A. INTRODUCTION

One of the primary objects of the investigation described in this report was to compare the performance of weavers under the conventional direct method of artificial lighting, by means of light sources mounted vertically above the work, with performance under a system employing special fittings arranged to direct light on to the work either from the side or the front of the looms.

Such a system, using concentrating fittings mounted with their principal axis at an acute angle with the horizontal plane of work and directing the light across the warp from left to right, has been the subject of experiment in Germany.\* It is claimed that this method of lighting increases the visibility of the warp threads, thus improving weaving efficiency and reducing the number of faults made by the weaver. The use of such a system appears to have been suggested by the fact that, in Germany, weaving sheds often have side windows, so that weaving is normally done in daylight received from the side of the looms. The method of artificial lighting described, thus imitates daylight conditions in this respect.

In this country, however, the almost invariable practice is to weave in sheds provided with roof windows, so that daylight is received from sources situated above the looms and cross-lighting will not reproduce the directional characteristics of daylight to which the weavers are normally accustomed. Nevertheless, this system would clearly be advantageous when compared with conventional methods of artificial lighting, if it increased the visibility of the work without, at the same time, introducing any disadvantageous condition.

### B. METHOD AND SCOPE OF THE INVESTIGATION

The investigation was carried out in a Yorkshire worsted weaving shed, hourly records of the performance of a group of six night weavers being obtained during a number of experimental lighting periods. The performance of the weavers in each of these periods, which were usually of five weeks' duration, is compared with their

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\* Die wirtschaftliche Beleuchtung von Webstühlen bei mattem Fadenmaterial; neue arbeitstechnische Untersuchungen. By N. Goldstern and F. Putnoky. *Licht und Lampe*, Nos. 1 and 2. Berlin, 1931.

performance under the original conditions of lighting, and also with the performance of a corresponding group of day weavers operating the same looms.

Before experiments with different methods of lighting were started, the effect upon performance of increasing the intensity of illumination, while adhering to the direct and most commonly used localised general method, was studied. The intensity of illumination was varied by increasing the wattage of the lamps used and retaining the same type, though not the same size, of reflector and approximately the same mounting positions and height. Thus, the original 60 watt lamps equipped with deep vitreous enamelled conical iron reflectors were replaced successively by 100, 150 and 200 watt lamps in standard dispersive type vitreous enamelled reflectors.

After the conclusion of these experiments, a system of general lighting was installed, using 200 watt lamps in mirror-glass reflectors designed to give a flux distribution providing a relatively high intensity of illumination on the vertical plane, so as to assist visibility at the reed and healds. Subsequently, vertical elliptical and elliptical angle reflectors were tried, the latter being arranged to direct the light into the healds from the front of the looms.

Finally, a system of cross-lighting, similar to that used by Goldstern and Putnoky in the German investigation referred to, was installed, using mirror-polished focussing reflectors suitably mounted.

The data obtained are given in full and discussed in Part II of this report, but the results are summarized below, together with the conclusions reached.

### C. SUMMARY OF RESULTS

In the first four lighting periods of this investigation the method of lighting was unchanged but the intensity of illumination was increased by increasing the wattage of the lamps used. The average output of the night weavers improved and, with the maximum illumination, reached a value which, having regard to the limitations imposed by other conditions, including the nature of the work, is probably about the maximum possible. But the average output of an equal number of day weavers, weaving the same cloth on the same looms, also improved during this stage of the investigation and reached its maximum in the period when maximum illumination was available at night. It must, therefore, be concluded that some change of conditions other than lighting occurred which facilitated production, so that the improvement of night output observed cannot be attributed entirely to the increase of illumination effected.

Any such change of conditions would affect the night weavers in the same way as the day weavers, though not necessarily to the same extent, but the best available measure of the effect of varying the conditions of lighting is the ratio of night to day relative output. (See Appendix I, p. 24.)

Measured in this way the maximum improvement of the night weavers occurred in the period when the first increase of illumination



was made. The actual illumination on the work was then approximately twice the original illumination. Averages of the photometric measurements in the most important areas of the field of work are—

	<i>Increased Illumination (Foot- candles).</i>	<i>Original Values (Foot- candles).</i>
Horizontal plane—		
On the cloth in front of reed .. .. .	29	13·3
On the warp near back lease rods .. .. .	13	5·3
On the shuttle-boxes .. .. .	12	6·0
Vertical plane—		
At the top of the healds .. .. .	13	7·0
On the shuttle-boxes .. .. .	6	3·0

The improvement of output which occurred with these conditions of illumination was 5·3 per cent., and to secure this improvement the time during which the looms were stopped while the weavers performed the necessary hand-work had to be reduced to an extent which represented an improvement of 24 per cent. in the personal efficiency or rate of working of the weavers. (See Table II and Fig. 6, p. 15.) Consideration of the visual requirements of the work, and of the output level achieved with the original illumination, suggests that this improvement may be about the maximum which can be expected to result from any increase of illumination. Further, with these conditions of lighting the greatest relative improvement also occurred in the quality of the work done, so far as this can be judged by the reduction effected in the time required to mend faults in the woven cloth. (See Figs. 7, p. 15, and 8, p. 16.)

In subsequent lighting periods several different types of reflector were tried, each having light flux distribution characteristics which appeared to be particularly suitable for the lighting of looms, inasmuch as they ensured a relatively high illumination on the vertical plane.

The first of these experimental installations consisted of 200 watt lamps in symmetrical mirror-glass reflectors giving maximum candle power at an angle of approximately 45 degrees to the vertical axis of the fitting. The fittings were mounted and spaced, in accordance with a scheme prepared by the makers, so as to provide general illumination of the shed. The intensity of illumination on the work was much less than that provided by the three preceding installations, and was lower than that provided by the original installation. Diversity of illumination was, however, also considerably reduced and the distribution on the vertical plane in which the healds lie, and on the vertical planes at right angles to this, in which the warp threads lie, was improved, though it was not better than that of the original installation. The general appearance of the shed was good, but the weavers complained of troublesome shadows and insufficient light. The level of output maintained with this installation was very good and the apparent improvement of

output, compared with that of the day weavers, was high. The latter, however, is partly attributable to a fall in the output of the day weavers, probably due to unfavourable conditions of warmth, and there is some reason to believe that the former may be partly due to a special effort to overcome the handicap of inadequate illumination or shadows. Though their significance is modified by these remarks the results obtained with this installation are such as to suggest that, if planned to provide a higher intensity of illumination on the work, it would prove very satisfactory. The mending time during the period this installation was in use was approximately the same as that for the preceding period.

Good results were obtained with a mixed installation consisting of vertical elliptical and elliptical angle reflectors with 200 watt lamps, arranged for localised general lighting. This was mainly due to the improvement of output of three weavers whose looms were lighted by vertical elliptical units. The illumination intensity provided on the healds by the elliptical angle units, which were mounted to face the front of the looms, was similar to that obtained with standard dispersive reflectors equipped with 200 watt lamps. With the vertical elliptical units the illumination on the healds was approximately the same as that given by 100 watt lamps in standard dispersive reflectors.

When all the looms were lighted by means of 200 watt lamps in elliptical angle reflectors the results obtained were unsatisfactory, probably owing to discomfort due to the heat to which the weavers' heads were exposed by close proximity of the lamps, and to the associated feeling of dissatisfaction. Reduction of the wattage of the lamps used to 150 practically eliminated the discomfort due to heat, and the night weavers' output then improved. The extent of the improvement during the first five weeks of this lighting period, having regard to the high output level then attained by the day weavers, suggests that the conditions of lighting were better for weaving than those in the control period. But, if account is taken of the relative output of the night and day weavers for the whole period of seven weeks during which 150 watt lamps in angle-elliptical reflectors were used, it may be seen that the difference between this and the control period is not significant, and that the mending time was substantially longer than in the five preceding lighting periods. The illumination on the healds was approximately equal to that given by 150 watt lamps in standard dispersive reflectors and the illumination on the horizontal plane of work was about 16 per cent. less than that given by 100 watt standard dispersive units.

The final installation consisted of 150 watt lamps in mirror-finished focussing reflectors mounted to direct the light across the front of the looms from the side. The primary object of this arrangement was to obtain a relatively high thread brightness on one side of the warp threads and thus to increase their visibility. Though this object was achieved the improvement in visibility was not great, and glare from the light sources was experienced by the weavers.

The relative improvement of output was good, though less than that obtained with the first experimental installation. An attempt was made to try this method of lighting using 100 watt lamps, but owing to the highly concentrating candle-power distribution of the units, the resulting illumination was too patchy to be satisfactory unless additional units were used. The mending time increased considerably during the cross-lighting period and was about 16 per cent. longer than in the original lighting period.

#### D. CONCLUSIONS

From the foregoing summary it is apparent that none of the special installations tested resulted in any improvement of the night, as compared with the day, weavers' output equal to that which occurred when the original installation was replaced by one consisting of 100 watt lamps in standard dispersive reflectors arranged for localised general lighting. So far as the results of this investigation are concerned there is, accordingly, no evidence which suggests that they are better adapted for the lighting of looms.

In general it appears that an average illumination of about 30 foot-candles on the cloth is necessary for high efficiency in weaving fairly dark cloth, and, if this intensity is obtained by means of a suitable arrangement of units whose candle-power distribution is similar to that of the standard dispersive reflector,\* the illumination of other portions of the field of work with which the weaver himself is concerned will be adequate.

The most economical arrangement of units appears to be one which provides for localised general lighting, but with certain types of loom, including those used in the shed here considered, parts of the loom which require adjustment by the loom tenter will not be adequately illuminated by this arrangement and some supplementary general lighting is desirable. General lighting alone would be satisfactory if planned to provide the necessary illumination on the work.

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\* British Standard Specification No. 232-1935. The light distribution from this fitting is dealt with in *Technical Paper No. 3 of the Illumination Research Committee*, H.M.S.O., London, price 1s. 0d.

## PART II

## A. REQUIREMENTS OF LOOM LIGHTING

The proper lighting of looms requires that the whole area occupied by the warp in the horizontal plane shall be illuminated to an intensity which will ensure good visibility of the warp threads, since the weaver has to keep the whole of this area under observation and may have to repair a yarn breakage in any part of it. In addition, the reed and healds, which lie in a vertical plane, must be adequately illuminated as the weaver has, not infrequently, to draw an end through them, and to draw it through the correct heald-eye and reed-dent. The illumination of these parts is not easy, indeed the provision of sufficient light at the inner healds, where a number of these have to be used to obtain the required cloth pattern, is perhaps the most difficult problem of loom lighting. The shuttle boxes also require to be well lighted, since the weaver has to watch the shuttles and observe when the weft is running low on the pirn, so that the loom may be stopped for re-shuttling before the weft runs out, otherwise a "broken pick" may be made which the weaver must pick out. As the shuttle-boxes are in motion, and there may be as many as six or eight of them to watch—the upper boxes obstructing the entry of light into the lower ones—it will be appreciated that adequate illumination of them is not easy to secure. Obviously, failure to provide these parts of the loom with sufficient illumination will increase the loom stoppage time and so reduce weaving efficiency. The back of the loom also requires good lighting in order to permit the ready detection and mending of broken warp ends, while other parts of the loom, such as the dobby mechanism, must be sufficiently illuminated to enable adjustments to be made quickly when necessary.

All these requirements appear to be best satisfied by the method of natural lighting from roof windows which is customarily used in weaving sheds, and a system of general\* artificial lighting would provide the best approximation to daylight conditions. In order to obtain the required intensity of illumination on the warp as economically as possible, local or localised general lighting is most commonly employed, though general lighting is being adopted to an increasing extent and, where the cloth woven is generally light in colour, a sufficient intensity can easily be obtained by this method without high cost.

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\* *General Lighting* = a system in which the spacing-height ratio of the light sources is arranged so that substantially uniform illumination is provided on the horizontal plane throughout the workshop.

*Localised General Lighting* = a system in which the light sources are mounted and grouped to provide substantially uniform illumination over relatively large areas of work, but giving less uniformity throughout the workshop as a whole.

*Local Lighting* = a system in which separate light sources are provided for each workplace, usually so mounted as to provide high illumination on the work and relatively low illumination on the surrounding area.

## B. DATA OBTAINED

The output of a group of six night weavers was measured by means of pick-recorders fitted to the looms. The latter were read at hourly intervals throughout the night, except for two half-hour periods, one at the end of the first spell and the other at the beginning of the third spell. The picks recorded during these half-hour periods have been converted to hourly values. The first reading each night was taken immediately before work began, and the difference between this and the last reading taken after completion of the previous night's work gives the daily output of the corresponding day weavers.

The hours of work of night weavers were as follows: 7.30 p.m. to 11.0 p.m., 11.30 p.m. to 3.30 a.m., 4.0 a.m. to 6.30 a.m. The night was thus divided into three spells with half-hour intervals between them. On Wednesday nights the duration of the first interval was extended to one hour to allow for cleaning. The night weavers worked five nights a week, while the day weavers worked  $8\frac{1}{2}$  hours per day, except on Saturday when worked finished at 12.30 p.m.

During seasons when the hours of darkness were not co-extensive with the hours worked by the night weavers, the time when the artificial lights were switched on and off was noted each night. Fig. 9 (p. 19), shows the average hours of daylight available per night shift for each week of the period of investigation. The temperature in the shed was also recorded during each spell of the night in the summer and autumn months. The average nightly shed temperature during each week is shown in Fig. 10. In addition, the duration of each loom stoppage and the cause of stoppage were recorded, with the exception of stoppages for re-shuttling. The time required to mend the faults in each piece of cloth woven was also obtained, this being the only available measure of the quality of the work done.

The looms were of the dobby type, having a reed width of 84 inches and were run at a speed giving 100 picks per minute. The maximum output with continuous running would thus be 6,000 picks per hour and the weaving efficiency, expressed as a percentage, is given by the ratio of actual to maximum possible picks multiplied by 100.

The same type of cloth—men's suitings—was woven in all the lighting periods. The colour and the pattern woven by individual weavers was changed from time to time, but in each lighting period the number of warps of each colour and pattern woven by the group was approximately the same, so that the average difficulty of the work, so far as it is determined by these characteristics, did not vary appreciably. A few white warps were woven but the majority were greys, browns and navy blues, while the patterns were stripes, herringbones, pinheads and checks. The reflection factors of a number of typical cloths were measured and these ranged from 0.37 for the white to 0.03 for the blue, the average being 0.043.

TABLE I.—Particulars of lighting installations.

Reflectors and Lamps.	Watts per Loom.	Illumination—Foot-candles.*										Weavers' Comments.	
		Front Horizontal on the Cloth.			Back Horizontal on the Warp.			Front Vertical at the Healds.			At Shuttle Boxes.		
											Horiz-ontal.		Ver-tical.
A { Deep conical enamelled iron with 60 watt lamps, 2 in front of each loom, 1 per pair of backs.	150.0	16.0	8.0	16.0	4.0	8.0	4.0	8.0	5.0	8.0	6.0	3.0	Not bad.
B { Vitreous enamelled standard dispersive with 100 watt G.F.lamps, 2 in front, 1 per pair of backs.	250.0	32.0	25.0	32.0	10.0	20.0	10.0	15.0	10.0	15.0	12.0	6.0	Better.
C { Standard dispersive with 150 watt G.F. lamps, 2 in front, 1 per pair of backs (200 watts).	400.0	40.0	30.0	40.0	18.0	32.0	18.0	17.5	13.0	17.5	15.0	7.0	Good, no need to improve this.
D { Standard dispersive with 200 watt G.F. lamps, 2 in front, 1 per pair of backs.	500.0	48.0	40.0	48.0	18.5	30.0	19.0	19.0	14.0	19.0	22.0	7.0	Very good.
E { Mirror-glass reflectors with 200 watt G.F. lamps arranged for general lighting, mounting height 10 ft. 6 in. above floor.	328.5	8.8	8.0	8.3	7.8	7.5	7.0	4.8	4.9	4.8	8.0	3.0	Bad shadows moving with the "going part." System not liked.
F & F <sub>1</sub> { Vitreous enamelled elliptical angle reflectors with 200 watt G.F. lamps, 2 in front, 1 S.D.R. per pair of backs.	500.0	42.5	28.0	39.0	18.0	25.0	18.0	20.0	15.5	19.0	18.0	7.5	Good light, but heat from lamps objectionable.
F <sub>1</sub> { Vertical, elliptical reflectors with 200 watt G.F. lamps, 2 in front, 1 S.D.R. per pair of backs.	500.0	54.0	39.0	51.0	18.0	25.0	18.0	14.0	9.0	15.0	19.0	6.0	Good.
G { Vitreous enamelled elliptical angle reflectors, 150 watt lamps, 2 in front, 1 S.D.R. per pair of backs (200 watt).	400.0	26.5	20.0	26.5	17.0	24.0	17.0	18.0	13.0	18.0	12.0	6.0	Not liked so well as standard dispersive reflectors.
H { Focussing mirror reflectors with 150 watt lamps arranged for cross-lighting, 2 in front, 1 S.D.R. per pair of backs (200 watt).	400.0	34.0	28.0	32.0	18.0	26.0	18.0	18.0	18.0	18.0	18.0	12.0	Glare experienced from units. No advantage over other systems.

\* See Fig. 1 for positions at which illumination was measured.

### C. ILLUMINATION

The illumination provided by each installation was measured at three points on the cloth in front of the reed, i.e. at a point near each selvedge and at the mid-point, and, similarly, at three points on the warp at the back of the healds near the lease-rods. The illumination was also measured at three points on the vertical plane at the healds, and also on the horizontal and vertical planes at the shuttle-boxes. The average of the measurements made at each of these points with the original lighting and with each experimental installation is given in Table I, together with particulars of the lamps and fittings used and the wattage per loom.\*

The positions at which the illumination was measured are shown in Fig. 1 (p. 10), and the arrangement of the light sources during the first four lighting periods is shown in Fig. 2. The arrangement of the mirror-glass reflectors is shown in Fig. 3, and of the elliptical-angle and focussing cross-light fittings in Figs. 4 and 5.

The original illumination† was not low (see A in Table I), considered in relation to current textile practice, and the weavers were not dissatisfied with it. The first experimental installation (B) approximately doubled the original illumination, and this was the greatest relative increase of illumination effected during the investigation. The second change (C) effected a further increase of illumination of nearly 30 per cent., and about three times the original illumination was obtained when 200 watt lamps (D) were installed. The lowest illumination was that provided by the installation of mirror-glass fittings (E), except on the warp at the back of the healds where it was higher than that given by the original installation. There was, however, less diversity with this installation than with the others since the fittings were mounted and spaced to give general lighting.

### D. DISCUSSION OF RESULTS

The average hourly output (in picks, i.e. weft threads woven) per loom of the "average" night and day weaver during each lighting period‡ is given in Table II (p. 13).

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\* In their experiments with cross-lighting, Goldstern and Putnoky used a maximum of 1,600 watts per loom, giving an illumination of 200 foot-candles on the horizontal plane of work. They state that an increase of output of 12.4 per cent. was obtained with this illumination (the original illumination was about 16 foot-candles) and that, up to 80 foot-candles, quality improved by 79 per cent. but the improvement diminished with higher values of illumination. It is not clear why the optimum illumination for quantity of output should be two and a half times as high as the optimum for quality. These results refer to light-coloured cloth. For dark cloth, output is stated to have increased by 15 per cent. at 200 foot-candles when quality also improved by 63 per cent. Economically the maximum benefit from improved lighting was secured with an expenditure of 230 watts per loom.

† The original illumination was approximately the same as that found by Goldstern and Putnoky in their investigation.

‡ A note on the comparability of the lighting periods with each other is given in Appendix I (p. 24).

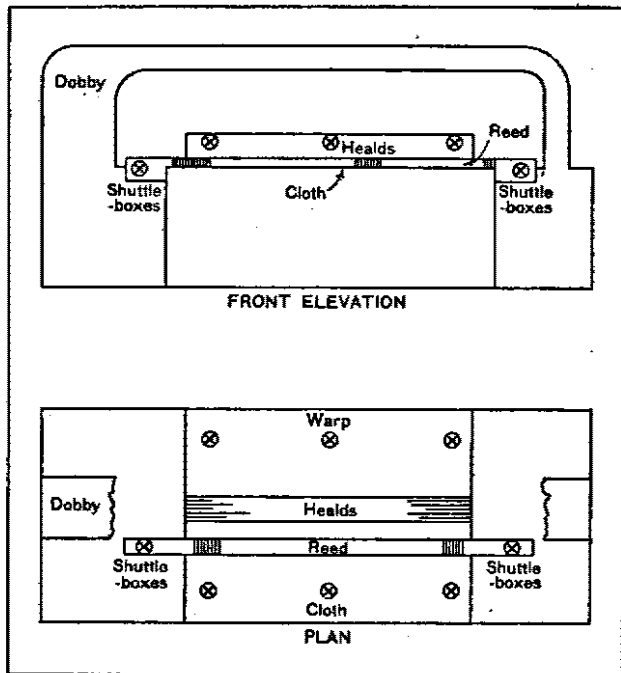


FIG. 1.—Diagrammatic plan and elevation of loom showing points of measurement of illumination on the horizontal and vertical planes.

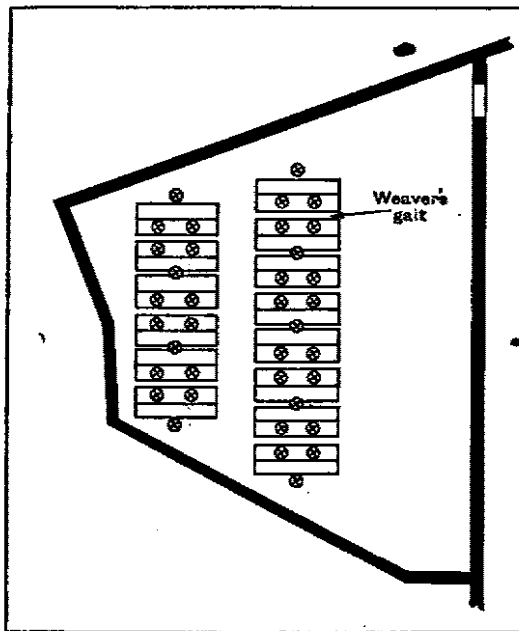


FIG. 2.—Plan of weaving shed showing arrangement of looms with positions of original light sources and of subsequent standard dispersive units.



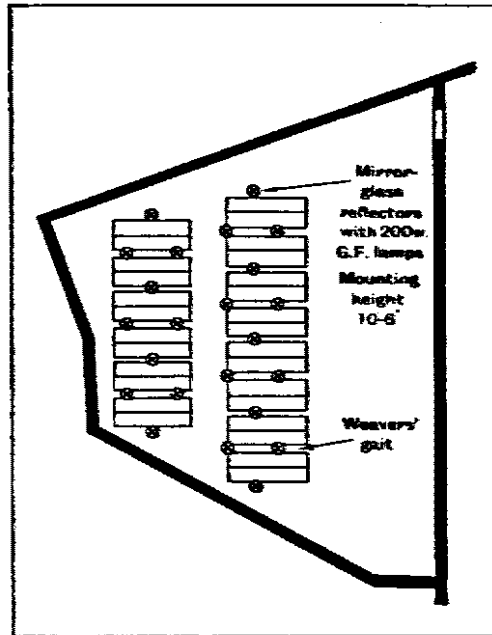


FIG. 3.—Plan of weaving shed showing arrangement of mirror-glass units for general lighting.

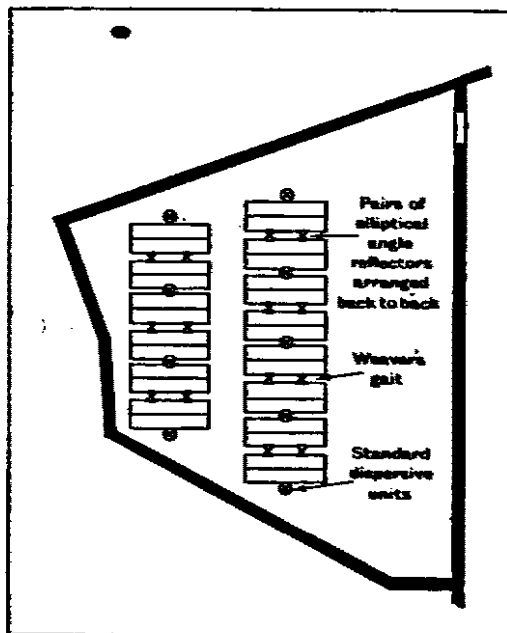


FIG. 4.—Plan of weaving shed showing arrangement of elliptical angle lighting units.

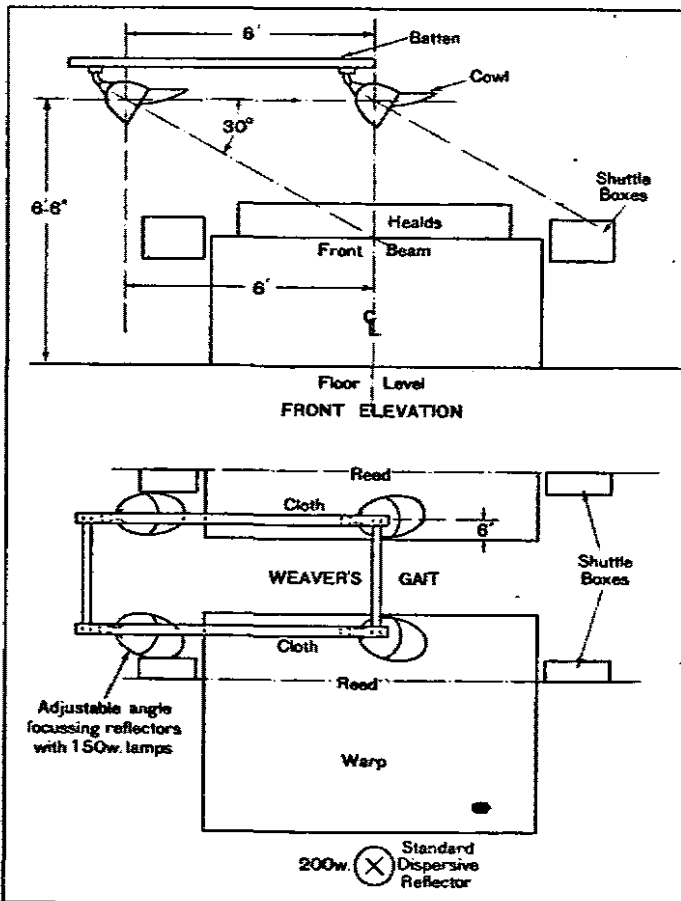


FIG. 5.—Diagram showing arrangement of focussing reflectors for cross-lighting each pair of looms.

The probable error of the weaver period-averages, from which the period-average output of the "average" night weaver is obtained, varies for different weavers from 0.5 to 1.4 per cent. For the "average" night weaver it is of the order of 0.8 per cent. in most lighting periods, but is somewhat higher for the day weavers.

In Table III (p. 14) the output of the average night weaver in the control (original lighting) period, and that of the average day weaver in the same period, is taken as 100 and the actual output in succeeding periods expressed as a percentage of this standard. The time spent in doing handwork (i.e. loom stoppage time) is similarly expressed, and the percentage increase or decrease of output and personal efficiency (rate of doing handwork) of the night as compared with the day weavers is given. The latter data are also represented graphically in Fig. 6 (p. 15).<sup>\*</sup> The quality of the work done can only be

<sup>\*</sup> The significance of output changes, and the limitation imposed by the nature of the work on their possible magnitude when lighting is improved, is discussed in Appendix II.

TABLE II.—Average hourly output per loom of the "average" night and day weaver in each lighting period.

Lighting Periods.											
	A Original	B 100 w. S.D.R.	C 150 w. S.D.R.	D 200 w. S.D.R.	E 200 w. M.G.	F 200 w. V.E. & E.A.	F <sub>1</sub> 200 w. E.A.	G 150 w. E.A.	G <sub>1</sub> 150 w. E.A.	H 150 w. C.L.	H <sub>1</sub> 150 w. C.L.
	5 weeks	4 weeks	5 weeks	5 weeks	5 weeks	2 weeks	1 week	7 weeks	1st 5 wks.	9 weeks	Mid. 5 wks.
Night..	4,450	4,702	4,594	4,801	4,790	4,759	4,611	4,697	4,807	4,473	4,499
*	±4%	±3.6%	±5%	±3.8%	±3%	±2.6%	±6.8%	±4.5%	±4.7%	±5.4%	±5.5%
Day ..	4,365	4,381	4,286	4,665	4,470	4,529	4,643	4,589	4,654	4,188	4,241
*	±2.5%	±4.5%	±5.7%	±4.1%	±4%	±6%	±6.1%	±3.5%	±3.8%	±3.9%	±3.8%

\* Per cent. mean variation of individual weaver's average output per loom from the average output of the "average" weaver.

100 w. = 100 watt lamps.  
 S.D.R. = Standard dispersive reflectors.  
 M.G. = Mirror-glass reflectors—general lighting.  
 V.E. = Vertical elliptical reflectors.  
 E.A. = Elliptical angle reflectors.  
 C.L. = Cross-lighting.

TABLE III.—*Relative output, and relative time on handwork, of night and day weavers.*

Lighting Periods	A Original 5 weeks	B 100 w. S.D.R. 4 weeks	C 150 w. S.D.R. 5 weeks	D 200 w. S.D.R. 5 weeks	E 200 w. M.G. 5 weeks	F 200 w. V.E. & E.A. 2 weeks	F <sub>1</sub> 200 w. E.A. 1 week	G 150 w. E.A. 7 weeks	G <sub>1</sub> 150 w. E.A. 1st 5 weeks	H 150 w. C.L. 9 weeks	H <sub>1</sub> 150 w. C.L. Mid. 5 weeks
Relative Output of Night Weavers.	100.0	105.7	103.2	107.9	107.6	106.9	103.6	105.5	108.0	100.5	101.1
Relative Output of Day Weavers.	100.0	100.4	98.2	106.9	102.4	103.8	106.4	105.1	106.6	96.0	97.2
Per cent. increase or decrease of Night compared with Day Output.	±0.0	+ 5.3	+ 5.1	+ 0.9	+ 5.1	+ 3.0	- 2.6	+ 0.4	+ 1.3	+ 4.7	+ 4.0
Relative Time on Night Handwork.	100.0	84.0	91.0	77.4	78.1	80.0	89.8	84.3	77.0	98.7	97.0
Relative Time on Day Handwork.	100.0	99.0	105.0	81.6	93.6	90.0	83.0	86.3	82.5	111.0	107.6
Per cent.* increase or decrease of Night compared with Day Weavers' Personal Efficiency.†	± 0.0	+24.1	+21.3	+ 6.4	+25.9	+15.9	-10.0	+ 2.8	+ 8.6	+17.7	+15.4

\* Per cent. increase or decrease, etc. =  $\left( \frac{\text{Rel. Night Output}}{\text{Rel. Time on Night Handwork}} \times \frac{\text{Rel. Time on Day Handwork}}{\text{Rel. Day Output}} - 1 \right) \times 100$

† Personal efficiency = weavers' rate of doing handwork. (See Appendix II.)

judged by the time required to mend (make good any faults) each piece of cloth woven, and the average mending time per piece for each lighting period is shown in Fig. 7, while the percentage by which the average mending time in the control period was reduced or exceeded in each lighting period is shown in Fig. 8. It was, unfortunately, not possible to apportion the mending time as between day and night weaving faults, so that a reduction of mending time does not necessarily mean that fewer faults for which the weaver is responsible, were made by the night weavers. There may, of course, have been fewer faults made by the day weavers, or fewer faults made by both groups, but if it is assumed that the day weavers

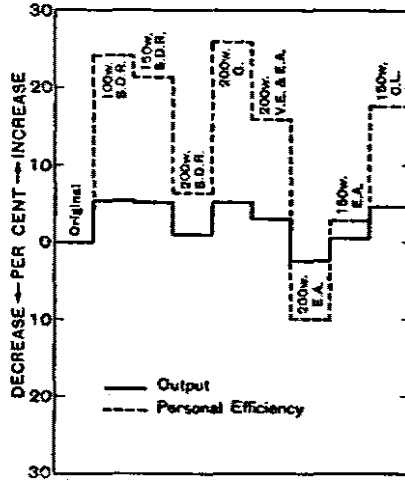


FIG. 6.—Per cent. increase or decrease of night weavers' output compared with day weavers' output, and corresponding increase or decrease of personal efficiency (rate of doing handwork).

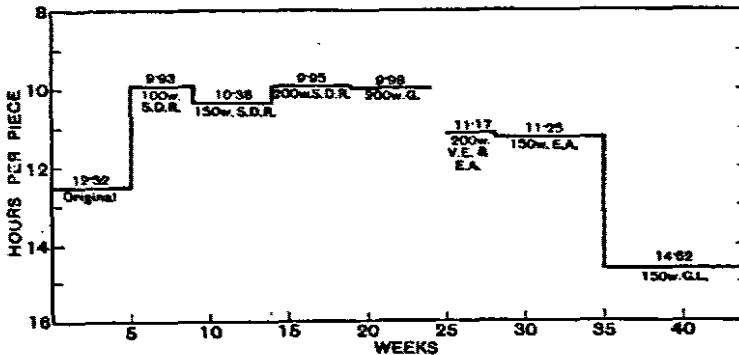


FIG. 7.—Mending time—Average hours per piece in each lighting period. The gap in the curve at about 24–25 weeks represents a holiday.

worked with ample illumination, an assumption which is probably quite justified except in respect of two to three hours a day during

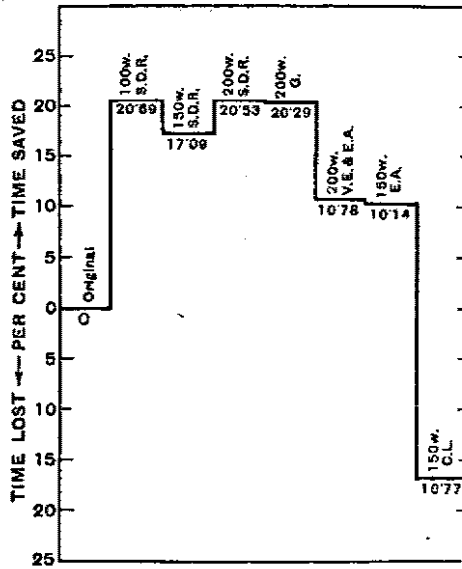


FIG. 8.—Percentage by which original mending time per piece was reduced or exceeded in each lighting period.

$$\left(1 - \frac{MT_1}{MT_0}\right) \times 100.$$

the first and last periods of the investigation, then it is more likely that any reduction of mending time will be due to fewer faults made by the night weavers, in consequence of increased illumination, than that it will be due to a chance variation in the number of faults made by the day weavers. On the other hand, it is possible that the mending time may be reduced because the cloth has fewer faults which are not due to the weaver, e.g. yarn faults, warping faults, and others which may originate in the processes to which the yarn is subjected preparatory to weaving, and also because of an increase in the efficiency of the menders. Too much importance cannot, therefore, be attached to the mending time as a criterion of quality of the night weavers' work.

By reference to Table III, and consideration of the relative output of the night weavers alone during periods of equal duration, it will be seen that the best result is obtained with 150 watt lamps in elliptical angle reflectors ( $G_1$ ), but the output is nearly as high with 200 watt lamps in standard dispersive reflectors (D) and with the installation for which 200 watt lamps in mirror-glass reflectors were used (E). The high output with the latter system is difficult to understand, since the illumination provided, both on the horizontal and vertical planes was actually lower than with the original lighting installation, except on the warp at the back of the healds.

If this high output is due to lighting it can only be explained on the ground that the intensity of illumination provided, and, therefore, the original intensity also, is quite adequate for the work and that the *method* of lighting, i.e. general instead of local or localised general, is the significant factor. The subjective evidence of the weavers does not support such a conclusion. They complained of troublesome shadows and insufficient light and thought the installation inferior to those preceding it. Further, if such a conclusion is accepted then the improvement noted in the preceding lighting periods cannot be attributed to the lighting since the only change then made was one of intensity, the method of lighting remaining essentially the same as that originally used. It seems probable that the maintenance of a high output during the general lighting period (E) was due partly to an effort to maintain high wages, in view of the approaching annual holiday, and possibly to a more or less conscious attempt to compensate for the effect of insufficient illumination. If the latter was made it appears, from the mending time, to have been successful in maintaining good quality as well as high output of work.

It must, therefore, be concluded that the high efficiency of the general lighting period is not due to the conditions of lighting then prevailing though, of course, it does not follow that the latter were not superior to those of the control period in some respects. Indeed, there is no apparent reason why the type of installation used in the general lighting period should not be as satisfactory as the others tried if it is planned to provide approximately the same intensity of illumination.

If the relative output of the night weavers is considered in relation to that of the day weavers in each lighting period the maximum gain will be found to occur in the first experimental period (B) when illumination was provided by means of 100 watt lamps in standard dispersive reflectors. Next in order of magnitude is the result obtained when the lamp wattage was increased to 150 watts (C), and the result with the general lighting system (E), and, third, that obtained with the cross-lighting system (H) using 150 watt lamps. Here, again, it is necessary to explain, as far as possible, the apparent inconsistency of the results obtained with the high illumination provided in the period (D) when the 200 watt standard dispersive units were used and with the low illumination characteristic of the general lighting period (E). It will be noted that the small excess of output of the night weavers over that of the day weavers in the first of these periods is due, not to any fall of the night weavers' output but to a relatively greater rise of the day weavers' output as compared with their output in the preceding period. This rise to what is, in fact, the peak value for the day weavers recorded during the investigation may be due to the influence of seasonal conditions, i.e., conditions of natural lighting and temperature which are probably most favourable to the achievement of high output at the time in question—the month of June, and also to the "spurt" which frequently occurs during

some weeks before an approaching holiday. In the case of the night weavers, however, the peak value of output is also reached in this period, but it must be remembered that there is a definite limit to the height of the peak which can be reached by either group and this limit is set by the nature of the work done, e.g., cloth woven, by the maximum working capacity of the weavers, and by the general organization for production, including arrangements for servicing the weaver, for which the management is responsible. Providing these factors remain unchanged it is obviously impossible by any change of lighting conditions to overcome the limitations they impose. Thus, there is little doubt that the level of output reached by the night weavers in the period under consideration (D) closely approaches the possible maximum, and, since conditions were favourable at least as regards lighting, for the achievement of maximum output by the day weavers, it is clear that only a small, if any, relative superiority of the night weavers can be expected.

With regard to the much greater apparent superiority of night output in the general lighting period (E), it will be noted that this is due to a serious fall of the day output level—not to a rise in night output—and it is probable that this fall was primarily due to the effect upon the weavers of the high shed temperature prevailing during this period, which at times reached 90° F. This factor would not affect the night weavers since the night average temperature (see Fig. 10, p. 19) was not excessive.

During the period when cross-lighting was used (H) the output of the day weavers reached its lowest level, but that of the night weavers did not fall below the level attained with the original lighting installation. The output gain of the night weavers suggests that this method of lighting was better than that of lighting from the front of the looms by means of elliptical angle units. The gain in this period, compared with that in the period (G) when 150 watt elliptical angle units were used, is not, however, quite so significant as the figures suggest, if allowance is made for what has been said regarding the effect of output level on the possible increase of output.

The main objection to cross-lighting, as used in this investigation, is the difficulty of avoiding glare from the light sources. The weavers saw no advantage in the system, but its novelty, and the existence of glare, may have biased their attitude towards it. The results obtained, however, do not show it to have any advantage over the more conventional and more easily installed systems of lighting giving equal intensity of illumination. Moreover, so far as the mending time can be taken as indicating the quality of the work done, cross-lighting appears to be inferior to all the other methods of lighting tried. The difficulty due to glare cannot be satisfactorily avoided merely by equipping the units with diffusing glass fronts, as, to some extent, this would defeat the purpose of the system which is to produce a high brightness on one side of the warp threads. The mounting height of the fittings might be increased, but if this



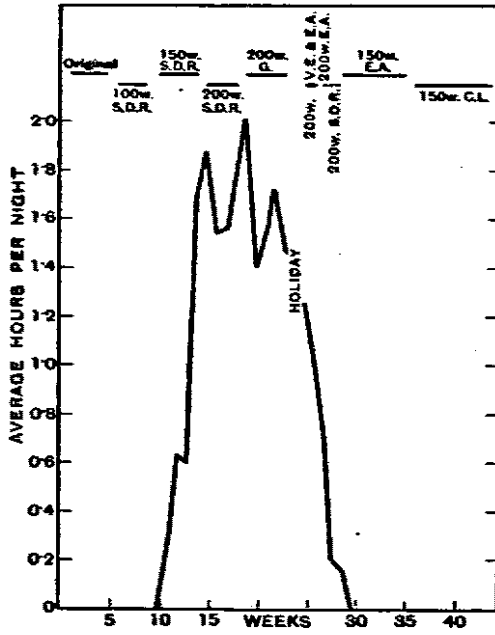


FIG. 9.—Average hours of daylight available per night shift during each week.

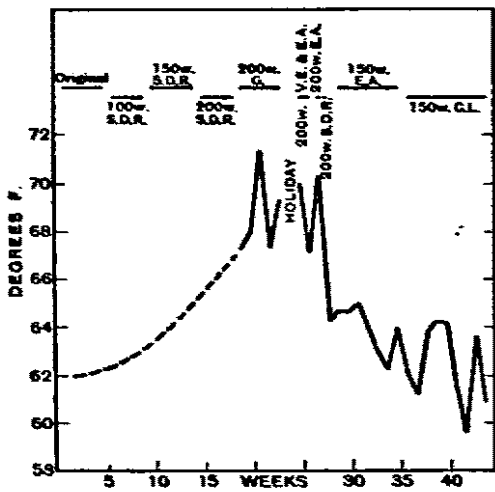


FIG. 10.—Average nightly shed temperature during each week.

is kept within practical limits, the system would still be inferior from the point of view of glare.

The results obtained with 150 watt elliptical angle lighting units are not as good as might be expected, though during the first five weeks ( $G_1$ ) of this period the output gain of the night weavers is very good considering the high level reached by the day weavers, and the fact that, owing to the positions in which the fittings had to be mounted, the weavers experienced some discomfort due to heat from the lamps in close proximity to their heads. Though the discomfort due to heat was not really serious, some of the weavers turned the fittings slightly outwards to avoid maximum radiation, and this increased the illumination of the shuttle-boxes. The difficulty due to heat was accentuated when elliptical angle reflectors were used with 200 watt lamps and, in consequence, they had to be abandoned after a trial of only one week ( $F_1$ ) during which the output of the night weavers dropped below that of the day weavers.

It was intended to install these fittings immediately after the annual holiday, but owing to a wrong delivery seven of the twelve looms had to be equipped with units consisting of 200 watt lamps in vertical elliptical reflectors, the remaining five having 200 watt lamps in elliptical angle reflectors. This mixed installation remained in use for two weeks. During this period ( $F$ ) the weavers working with elliptical angle units complained of heat from them, but the group output was very satisfactory and was 3 per cent. higher than that of the day weavers. If the results of the weavers working with vertical elliptical units and those working with elliptical angle units are considered separately, the former, three in number, show an average increase of output, on comparison with corresponding day weavers, of 5.6 per cent. The two weavers working with elliptical angle units (results for the sixth weaver are ignored as one of his looms was lighted by vertical elliptical and the other by elliptical angle units) show an average increase of output of only 2 per cent. when compared with the two corresponding day weavers.

Disturbing shadows cast on the cloth by the "going part," i.e. the moving sley carrying the reed and shuttle-boxes, were less with lighting from elliptical angle units than from vertical elliptical units and the illumination on the vertical plane at the healds was considerably higher, but these advantages do not apparently outweigh the disadvantage of discomfort caused to the weavers when high wattage lamps are used. Vertical elliptical units have the advantage of spreading the light flux transversely and thus, for equal wattage, provide higher illumination on the horizontal plane at the extremities of the cloth and on the shuttle-boxes than elliptical angle units, and the output of the three weavers considered above suggests that very good results can be expected from their use.

The greatest relative increase of illumination was effected when 100 watt lamps in standard dispersive reflectors ( $B$ ) were substituted for the original lamps and fittings, the illumination being then approximately doubled. The greatest increase of output of the night weavers,

compared with the day weavers, also occurred in this period. The magnitude of this increase may be influenced to some extent by "experimental effort," but clearly a relatively large increase would be expected in view of the big increase of illumination. In the next lighting period (C) the lamp wattage was increased to 150 and the actual output of the night weavers was then lower than in the preceding period, though the improvement in relation to the day weavers' output was maintained but not exceeded.

The mending time was considerably reduced in all the lighting periods up to and including the general lighting period (see Fig. 7, p. 15), but after the large reduction effected in the first experimental period (B) no further improvement occurred.

The group average weaving efficiency at each hour of the typical night in each lighting period is given in Table IV. Variations of efficiency during the night are due to the influence of a number of factors of which lighting, of course, may be one. If graphs of these hourly values of efficiency are plotted the general shape of all the curves is typical of most industrial work curves, being characterised, in each spell, by an initial upward slope to a peak at about the middle of the spell, followed by a downward slope in the latter part of the spell. This is also true of the night as a whole if the average hourly output in each spell is considered.

The difference between the peak efficiency and the efficiency at the beginning and end of the spell or night, and thus the slope of the work curves, may vary irrespective of the general level of the curve if the conditions of work are changed in such a way as to stimulate or depress initial effort, and diminish or increase the fatigue experienced. It may be expected, therefore, that these variations will give some indication of the comparative value of the different conditions of lighting tried.

In addition to the hourly weaving efficiency, Table IV (p. 22) gives the relative efficiency in each spell of the night. In each typical night the spell having the highest average hourly weaving efficiency has, of course, a relative efficiency of 100 per cent.

So far as the first spell is concerned, the relative efficiency does not differ to any important extent from that of the original lighting period, except in the second experimental period (C) and in the cross-lighting period (H). The low efficiency in these two periods cannot be attributed to the effect of lighting. In the cross-lighting period it may have been due to low shed temperature in the first spell, the average recorded being only 58.9° F.,\* but it cannot be satisfactorily explained in the period when lamps of similar wattage were used in standard dispersive reflectors.

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\* This is several degrees below the dry bulb temperature found by Bedford to give maximum comfort for persons doing very light work under conditions comparable with those in the small shed in which this investigation was made. The work of the weaver is light rather than very light in character but, even so, the temperature recorded is probably too low for maximum comfort—see "The Warmth Factor in Comfort at Work," by T. Bedford, *Report No. 76 of the Industrial Health Research Board*. H.M.S.O., London, 1936.

TABLE IV.—Variation of group average weaving efficiency during the typical night of each lighting period, and relative efficiency in each spell of the night.

Lighting Installation.	Hours.											Per cent. Mean Variation from Average Hourly Efficiency.	
	1st Spell.				2nd Spell.				3rd Spell.				
	1	2	3	4	5	6	7	8	9	10	11		
Original	A	74.0	77.9	78.9	72.9	76.3	79.4	77.4	71.6	68.1	77.4	62.3	±5.4
		99.7				100.0				90.9			
100 watt S.D.R.*	B	79.2	82.1	82.7	74.6	80.4	81.9	80.7	76.7	76.0	81.7	66.7	±4.5
		99.7				100.0				93.6			
150 watt S.D.R.	C	77.7	80.2	79.4	68.8	81.2	81.5	82.4	75.8	72.3	79.4	63.3	±6.2
		95.4				100.0				89.3			
200 watt S.D.R.	D	81.3	83.6	86.3	74.7	80.7	83.3	82.8	78.1	80.1	83.4	65.9	±4.9
		100.0				99.7				93.9			
200 watt M.G.*	E	82.9	85.0	85.2	71.9	81.8	82.8	83.4	78.4	76.1	82.3	68.4	±5.6
		99.5				100.0				92.7			
200 watt V.E. & E.A.*	F	79.1	84.3	82.4	73.5	80.6	82.8	83.9	77.5	77.7	84.7	65.9	±5.2
		98.3				100.0				93.7			
200 watt E.A.*	F <sub>1</sub>	76.8	80.3	81.3	75.6	79.1	83.6	80.4	74.2	72.1	81.2	60.9	±5.9
		99.0				100.0				90.0			
150 watt E.A.	G	78.5	83.0	81.6	73.9	78.8	81.5	83.3	77.7	79.0	81.0	68.6	±4.1
		98.7				100.0				94.8			
150 watt C.L.*	H	74.1	75.6	77.4	70.4	75.6	79.6	79.2	74.0	74.6	77.4	61.5	±4.7
		96.5				100.0				92.3			

Except in the second experimental period (C) and the single week period (F<sub>1</sub>) when elliptical angle reflectors with 200 watt lamps were used, the relative efficiency in the last spell was higher in the experimental lighting periods than in the original lighting period. The maximum improvement occurred in the period when elliptical angle reflectors were used with 150 watt lamps (G), and the least improvement occurred in the cross-lighting period (H). There is no significant difference between the improvement observed in the periods when 100 watt (B) and 200 watt (D) lamps were used in standard dispersive reflectors, and when the mixed installation of vertical elliptical and elliptical angle units (F) was in use. The improvement with each of these installations was nearly 4 per cent., and it was nearly 3 per cent. with the general lighting installation (E). The variability of efficiency during the night, shown by the percentage mean variation given in Table IV, was least during the two periods when the lighting installation consisted of 150 watt elliptical angle (G) and 100 watt standard dispersive units (B).

## APPENDIX I

**A NOTE ON THE COMPARISON OF NIGHT WEAVERS' OUTPUT IN DIFFERENT EXPERIMENTAL LIGHTING PERIODS, AND ON THE COMPARISON OF NIGHT WITH CORRESPONDING DAY WEAVERS' OUTPUT IN THE SAME PERIODS.**

In most field investigations it is exceedingly difficult to ensure that all the conditions within the factory which are capable of affecting the productive capacity of the worker shall remain constant, or nearly so, except the particular one the effect of varying which it is desired to study. This difficulty increases as the duration of the investigation is prolonged, for such conditions as those of temperature and natural lighting, for example, are subject to seasonal variation which cannot usually be confined within such narrow limits that its effect is negligible. In many cases also there are seasonal changes of product, particularly in certain textile factories.

Short period experiments, though permitting more rigid control of working conditions, are more likely to yield results which are influenced by "experimental effort," and it is known that the initial effects of changing some condition of work are not always maintained for long periods.

In the investigation described in the foregoing report the duration of each of the experimental lighting periods was usually five weeks and the investigation extended over a total period of ten months. It is obvious, therefore, that some conditions of artificial lighting had to be tried in summer and others in winter months, so that if a direct comparison is made between the results obtained in one lighting period and those in another any difference will not necessarily be wholly attributable to the difference of lighting but may be partly due to more, or less, comfortable conditions of warmth. It might be possible to estimate to what extent any such observed difference was due to the normal effect of seasonal changes, for example of temperature, by comparing the two periods under consideration with the corresponding periods of the previous year, or of several previous years, providing the nature of the work then done was strictly comparable. In the present case this procedure has not been possible.

Apart from seasonal changes, other conditions which affect the weaver vary from time to time to an extent which can be neither foreseen nor controlled, and it is not certain that the net effect of these variations will be the same in any two periods of five weeks' duration. For instance, a series of bad warps may occur in one period and not in another, and this will increase the difficulty of weaving though the kind of cloth woven remains the same.

In this investigation, however, the group of weavers selected for observation worked at night on looms which were also in operation during the day by a different group of weavers. It is thus possible to compare the output of the night weavers in any lighting period with that of the day weavers in the same period, both groups weaving the same cloth. Seasonal variations, and any variation such as in the difficulty of the work, will affect both groups of weavers and any difference between their respective performances, after allowing for any original group difference observed (which may be due to a difference of ability, or to a difference between the day and night loom speed due to variation of supply voltage), will then be at least mainly attributable to the change of lighting conditions imposed upon the night weavers.

However, if there is an improvement in daylight illumination this may raise the day weavers' output but will not affect that of the night weavers. Again, the day temperature may reach an uncomfortable level in summer and depress the day weavers' output, while the corresponding night temperature may have no unfavourable effect on the output of the night weavers. It is impossible to make any numerical corrections for the effect of such variations as these and they may, in some periods, depreciate the value of the day weavers' output as a standard of comparison. The extent to which any improvement of the night weavers' output is due to improved artificial lighting cannot, therefore, be exactly determined by this method though, on the whole, it probably gives a more reliable indication of the value of the lighting conditions

than does the comparison of the night weavers' output in the experimental lighting periods with their output under the original conditions of lighting.

Direct comparison can be made between the night and day weavers' performance in each lighting period if each performance is expressed as a percentage of the corresponding group performance achieved in the control period. The percentage gain, or loss, of performance by the night weavers will then be given by

$$\left( \frac{\text{night weavers' relative performance}}{\text{day weavers' relative performance}} - 1 \right) \times 100$$

## APPENDIX II

## THE SIGNIFICANCE OF OUTPUT CHANGES

## WEAVING EFFICIENCY AND PERSONAL EFFICIENCY (SPEED OF HANDWORK)

In the process of weaving the output, i.e., amount of cloth produced, in any unit of time is proportional to the machine running time. The latter can never be 100 per cent. of the time unit because the looms must be stopped periodically to enable the weft in the shuttles to be replenished. There are, however, always other causes of lost machine running time, of which the most important is the breaking of "ends" (warp threads) which have to be "taken up" by the weaver while the loom is stopped. Accordingly, in practice, the weaving efficiency (ratio of cloth woven to cloth which would have been woven without loom stoppages, expressed as a percentage) may be only 75 or 80 per cent. In order to increase the output say by 1 per cent. either the number or duration of loom stoppages, or both, must be reduced. Assuming that the stoppages are limited in number to those which are unavoidable, so that the loss of output depends only upon their duration, this loss can be reduced only by an increase in the rate of working of the weaver. But, to raise the output in this way by 1 per cent. from 4,500 picks per hour (75 per cent. efficiency with a loom speed of 100 picks per minute) to 4,545 picks per hour (75.75 per cent. efficiency), means that the proportion of the total working time occupied in handwork by the weaver must be reduced from 25 per cent. to 24.25 per cent., and in this time he must do all the handwork he previously did in 25 per cent. of the total working time plus a little more made necessary by the additional cloth woven during the extra machine running time. His rate of working is, therefore, increased by

$$\left( \frac{75.75 \div 24.25}{75 \div 25} - 1 \right) \times 100 = \left( \frac{75.75 \times 25}{24.25 \times 75} - 1 \right) \times 100 = 4.12 \text{ per cent.}$$

It is thus evident that in power-loom weaving a relatively large increase of personal efficiency is necessary to effect a small increase of output, and the latter, considered by itself, gives an inadequate idea of the benefit derived by the weavers from any improvement of conditions to which it is attributable.

## OPERATIONS IN WEAVING AFFECTED BY LIGHTING

It is mainly by making possible quicker perception of weft shortage—indicating the necessity for re-shuttling—and of warp breakages and the threads which have to be tied, and quicker discrimination of the heald eyes and reed dents through which broken "ends" may have to be drawn, that improved lighting can shorten the time occupied by the weaver in doing work requiring stoppage of the loom. Therefore, a very large reduction of handwork time cannot be expected, even with the best illumination, unless comparison is made with results obtained with extremely poor illumination. For example, a 12 per cent. increase of output, given an initial weaving efficiency of 75 per cent., would increase efficiency to 84 per cent., and would require the rate of handwork to be increased by 75 per cent. if the handwork required is proportional to the weaving efficiency. An improvement of this order would certainly be difficult to secure, as the result of improved visibility due to better lighting if the original lighting was good enough to permit an initial efficiency of 75 per cent.

## PROBABLE EXTENT OF OUTPUT GAIN OBTAINABLE WITH IMPROVED LIGHTING

If the initial efficiency is low, say 50 per cent., a 12 per cent. increase of output requires an increase in the rate of handwork of 27.27 per cent., but, at the higher initial efficiency considered above, a 12 per cent. increase of output could probably only be secured by eliminating or reducing other causes of lost machine running time, such as breakdowns, absence of the weaver



while fetching weft, etc., but these are losses, some of which are either not reducible at all or are only reducible to a slight extent by better lighting.

When the loom is stopped the weaver has both to look at objects and manipulate them. Unless the lighting is very bad, more time is spent in doing something than in seeing what has to be done. When the loom is stopped for re-shuttling the time occupied in performing this operation mainly depends on the weaver's rate of action. The need for quick perception occurs *before* the loom is stopped, when the weft is running low and, of course, if the lighting is bad and the weaver cannot see properly, the weft may run out before the loom is stopped and leave an incomplete pick in the cloth to be removed before the loom is re-started. It is possible that several picks may be missed altogether in this way, and the warp will then have to be pulled back to restore the cloth fell to its proper position in which it abuts against the reed when the latter is at the forward end of its stroke. Time and output are lost in this way, but failure to stop the loom before the weft in a shuttle is exhausted can, and often does, occur because the weaver is occupied in attending to his second loom and cannot, therefore, keep the other one under constant observation at the same time. Thus loss of machine running time due to this cause cannot be eliminated by improvement of lighting and is likely to be reduced very little by increasing illumination beyond the moderate intensity which suffices to enable the weaver to see when the quantity of weft remaining in the shuttle is becoming small enough to necessitate re-shuttling. If the cloth is a fancy one, such as a patterned suiting, for which several shuttles are used, each containing weft of different colour, there may be so little difference between the colours that time may be lost in selecting the right one for insertion, and this, of course, can be diminished by improving illumination. The actual insertion of a new pirn of weft into the shuttle is usually done while the loom is running, a spare shuttle being available, so that any time saved in doing this, due to better lighting—and it will not be great as this operation is controlled much more by manipulative skill than by vision—will not as a rule affect output.

Thus, so far as re-shuttling is concerned, it is apparent that, unless performance in very bad conditions of lighting is compared with that in good or very good lighting, the difference of loom stoppage time, and therefore of output, will be small. The cloth woven during this investigation necessitated re-shuttling on an average about fifteen times per hour per loom, and each re-shuttling required stoppage of the loom for about fifteen seconds. If no incomplete picks had to be removed the total re-shuttling time per hour thus amounted to about  $3\frac{1}{2}$  minutes. If, however, it is taken as four minutes, this is only 6.7 per cent. of the possible loom running time. Now, if better lighting increases the machine running time, and thus the output level, by reducing the time occupied in doing visual work when the loom is stopped, the increase of cloth woven would necessitate increased frequency of re-shuttling as well as of yarn breakage repair, so that the net time saved on re-shuttling under better lighting may be almost negligible. If, however, it is assumed that the net result of better lighting will be to reduce the hourly stoppage time by as much as 10 per cent. of the maximum re-shuttling time given above, i.e. by 0.4 minutes, and the initial weaving efficiency is 75 per cent. (the average weaving efficiency with the original lighting found in this investigation was 74.2 per cent.), then the loom running time will be increased to 45.4 minutes per hour, thus increasing the output by 0.89 per cent., and the overall rate of handwork by 2.74 per cent.

Apart from re-shuttling, the most important cause of lost machine running time which can be affected by lighting is the time required for piecing broken "ends." Here perception and discrimination play an important part in the work to be done, and more time may sometimes be spent in finding a broken end than in actually mending it, or in finding the appropriate heald-eye and reed-dent than in drawing a warp end through them. This, however, is by no means always the case, as a broken end may be easy to find or may be found partly by the sense of touch rather than sight. The actual operation

of piecing is quickly done, but, if several ends break at the same time, as often happens, the visual time element may be considerably increased in comparison with the manipulative time since care must be taken to piece the several threads in the correct sequence.

Obviously good lighting can reduce the time required for seeing in the process of piecing broken ends, but with the original lighting in the shed with which we are here concerned, it is doubtful whether the time occupied in seeing amounted to more than half the total time during which the looms were stopped for "taking up ends." An analysis of the stoppage times recorded during the first period of this investigation, with the original lighting, shows that, on the average, taking up ends occupied 30.32 per cent., or 3.335 minutes per hour, of the total stoppage time (excluding re-shuttling time) per loom. Assuming that 50 per cent. of this time is "seeing time" then, with a weaving efficiency of 75 per cent.  $(15-4) \times 0.3032 \times 0.5 = 1.67$  minutes per hour is occupied by visual work in connection with the repair of yarn breakages. If this time can be halved, i.e., the speed of vision doubled,\* by means of improved lighting the total stoppage time due to taking up ends will be reduced to  $3.335 - \frac{1.67}{2} = 2.5$  minutes per hour.

But since any time saved in this way, and added to the loom running time, proportionally increases the number of yarn breakages requiring repair, the effective additional loom running time will be less than 0.835 minute. Taking it as 0.8 minute, the loom running time will be increased from the 45.4 minutes found above to 46.2 minutes per hour, thus increasing output, due to quicker re-shuttling and piecing, by 2.4 per cent.

In addition to stoppages recorded for the purpose of taking up ends, others were due to the weaver having to attend to his other loom. This means that while piecing ends, taking a piece of cloth off the loom, or doing other necessary work on one loom, the other has sometimes to be stopped to avoid faulty weaving. Thus the stoppage of one loom for any reason often involves lost running time for both. This cannot be avoided by improving lighting but, obviously, if the piecing time is reduced the stoppage time required for attending to the other loom will also be reduced, though not to the full extent of the piecing time saved, since the work done on the other loom does not consist only of piecing broken ends. It is difficult to estimate very accurately what proportion of the time lost on one loom while attention is given to the other is due to that attention being required for the purpose of taking up ends. Some of this stoppage time will occur while a piece is being taken off the other loom, as stated above, or while a picking-stick strap is being mended, etc., and it is very doubtful whether more than 25 per cent. of the time saved in piecing ends on one loom will also be saved on the other owing to the increased attention which the weaver is able to give it.

The percentage of the total hourly loom stoppage time, due to all causes except re-shuttling, which was recorded as due to "attending to the other loom" with the original lighting was 21.83. With a weaving efficiency of 75 per cent. this is equivalent to  $(15-4) \times 0.2183 = 2.4$  minutes per loom per hour. As it has been assumed that 0.8 minute can be saved on piecing ends by means of better lighting,  $\frac{0.8}{4} = 0.2$  minute will be saved on attending to the other loom, thus reducing this stoppage time to 2.2 minutes per loom per hour.

\* With good contrast, having regard to the size of detail to be seen in worsted weaving, it would not be possible to double the speed of vision even by raising illumination to the high value of 500 foot-candles.† But if the contrast is poor and the material dark in colour, such a result may be possible—perhaps with a lower illumination.

† *Vide* "The Relation between Illumination and Industrial Efficiency. (1) The Effect of Size of Work." *Joint Report of the Industrial Health Research Board and the Illumination Research Committee.* H.M.S.O., London, 1935.

Taking the combined time saved on re-shuttling, piecing ends and attending to the other loom, i.e.,  $0.4 + 0.8 + 0.2 = 1.4$  minutes, the total stoppage time is reduced from 15 to 13.6 minutes per hour and the weaving efficiency is raised from 75 to 77.33 per cent. by a total increase of output of 3.11 per cent.

Time can be saved in connection with other operations, some of which are not performed by the weaver, but by the loom tender, but it is clear that the aggregate time which can be saved by improvement of lighting cannot be sufficient to produce a large increase of output if the initial efficiency is fairly high. Machine running time is lost, of course, from causes which cannot be influenced by lighting, such as the time lost when the weaver is away from the looms, and if this time can be reduced then a further improvement of output will be obtained. Much time may be wasted if the illumination is not sufficient to enable the weaver to detect a broken warp thread quickly, but this will be the time of the mender who has to sew in the missing portion of thread after the cloth is woven, and it will not, therefore, reduce the weaver's output.

So far, only the improvement of output likely to result from improved visual performance in connection with certain operations which normally account for more than half the total loom stoppage time has been considered. But manual performance may also improve with better lighting which induces feelings of well-being, contentment and alertness and thus tends to stimulate physical activity. This effect of lighting, primarily of a psychological nature, is due largely to the general appearance of the work-place. Investigation of this aspect of the problem of lighting, in the case of tile-pressers, has shown that when a local system of lighting, providing low illumination, badly distributed, so that the appearance of the work-place is gloomy and cheerless, is replaced by a general system, giving reasonable illumination, the rate of working is stimulated and output increased by about 6 to 10 per cent.\*

The change of intensity of illumination was from an initial average value of about 1 foot-candle to some 4 to 5 foot-candles. The output of the tile-pressers was entirely controlled by their rate of handwork, but that of the weavers here considered was controlled by the rate of handwork only for about one-quarter of the total production time so that, even if the psychological effect of better lighting upon the weavers was of the same order of magnitude as in the case of the tile-pressers a net increase of output of only about 2 per cent. could be expected. Since, however, the initial illumination in the weaving shed was higher than that in the re-lighted tile-pressing shop, and the general appearance was reasonably good, an even smaller improvement of output due to the psychological effect of better lighting must be expected, especially as the general appearance of the shed was not greatly changed by the means employed to increase the illumination on the work.

Thus, from the foregoing discussion, it is evident that if a large increase of output is secured when the initial efficiency is high it will probably be due partly to the variation of factors other than lighting. In the present case, from the improvement of lighting alone, it may be expected that output can be increased perhaps by 5 per cent. but it is doubtful whether a much better result can be achieved.

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\* *Vide* "The Effect of Lighting on Efficiency in Rough Work (Tile Pressing)," *Joint Report of the Industrial Health Research Board and the Illumination Research Committee*. H.M.S.O., London. 1936.

## LIST OF PUBLICATIONS

(The prices given are net : those in brackets include postage.)

December, 1937

The following publications relating to the work of the Industrial Health Research Board can be purchased directly from H.M. Stationery Office, at the following addresses: Adastral House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2; 26 York Street, Manchester 1; 1 St. Andrew's Crescent, Cardiff; 60 Chichester Street, Belfast; or through any bookseller.\*

## ANNUAL REPORTS

First to March 31st, 1920. 6d. (7d.); Second to September 30th, 1921 (with Analysis of Published Work). 1s. 6d. (1s. 8d.); Third to September 30th, 1922. 2s. (2s. 1½d.); Fourth to December 31st, 1923. 1s. 3d. (1s. 4d.); Seventh to December 31st, 1926. 9d. (10d.); Eighth to December 31st, 1927. 9d. (10d.); Ninth to December 31st, 1928. 9d. (10d.); Tenth to December 31st, 1929. 6d. (7d.); Eleventh to June 30th, 1931. 1s. 6d. (1s. 7½d.); Twelfth to June 30th, 1932. 1s. 0d. (1s. 1d.); Thirteenth to June 30th, 1933. 9d. (10d.); Fourteenth to June 30th, 1934. 9d. (10d.); Fifteenth to June 30th, 1935. 9d. (10d.); Sixteenth to June 30th, 1936. 9d. (10d.); Seventeenth to June 30th, 1937. 9d. (10d.)

The following reports are out of print and not included in the list, Nos. 25, 26, 28, 32, 34, 35, 36, 38, 42 and Annual Reports, Nos. 5 and 6.

## REPORTS CLASSIFIED ACCORDING TO SUBJECT MATTER

## (i). Hours of Work, Rest Pauses, etc.

- No. 1.—The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture, by H. M. Vernon. (1919.) 6d. (7d.)
- No. 2.—The Output of Women Workers in relation to Hours of Work in Shell-making, by Ethel E. Osborne. (1919.) 6d. (7d.)
- No. 5.—Fatigue and Efficiency in the Iron and Steel Industry, by H. M. Vernon. (1920.) 3s. (3s. 2d.)
- No. 6.—The Speed of Adaptation of Output to altered Hours of Work, by H. M. Vernon. (1920.) 1s. (1s. 1d.)
- No. 24.—A Comparison of different Shift Systems in the Glass Trade, by E. Farmer, R. C. Brooks and E. G. Chambers. (1923.) 1s. 6d. (1s. 7d.)
- No. 41.—Rest Pauses in Heavy and Moderately Heavy Industrial Work, by H. M. Vernon and T. Bedford, assisted by C. G. Warner. (1927.) 9d. (10d.)
- No. 47.—Two Studies on Hours of Work. I.—Five-Hour Spells for Women with reference to Rest Pauses, by H. M. Vernon and M. D. Vernon, assisted by I. Lorrain-Smith. II.—The Two-Shift System in certain Factories, by May Smith and M. D. Vernon. (1928.) 1s. 3d. (1s. 4d.)

*References, hours of work and rest pauses also occur in Report No. 56.*

## (ii). Dexterity

- No. 63.—Inspection Processes in Industry, by S. Wyatt and J. N. Langdon. (1932.) 1s. (1s. 2d.)
- No. 64.—A Classification of Vocational Tests of Dexterity, by A. E. Weiss Long and T. H. Pear. (1932.) 1s. 3d. (1s. 5d.)
- No. 66.—An Experimental Study of Certain Forms of Manual Dexterity, by J. N. Langdon. (1932.) 1s. (1s. 2d.)

\* For overseas agencies see last page.

- No. 67.—Manual Dexterity: Effects of Training, by E. M. Henshaw, J. N. Langdon and P. Holman. (1933.) 1s. (1s. 2d.)
- No. 73.—The Acquisition of Skill: Analysis of Learning Curves, by J. M. Blackburn. (1936.) 1s. 6d. (1s. 8d.)

#### (iii). Industrial Accidents

- No. 4.—The Incidence of Industrial Accidents, with special reference to Multiple Accidents, by Major M. Greenwood and Hilda M. Woods. (1919.) 6d. (7d.)
- No. 19.—Two Contributions to the Study of Accident Causation, by Ethel E. Osborne, H. M. Vernon and B. Muscio. (1922.) 1s. 6d. (1s. 7d.)
- No. 55.—A Study of the Personal Qualities in Accident Proneness and Proficiency, by E. Farmer and E. G. Chambers. (1929.) 3s. (3s. 2d.)
- No. 68.—Tests for Accident Proneness, by E. Farmer, E. G. Chambers and F. J. Kirk. (1933.) 9d. (10d.)

*References to industrial accidents also occur in Reports Nos. 39 and 62.*

#### (iv). Atmospheric Conditions

- No. 11.—Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories, by W. D. Hambly and T. Bedford. (1921.) 3s. (3s. 2d.)
- No. 18.—Two Investigations in Potters' Shops, by H. M. Vernon and T. Bedford. (1922.) 2s. 6d. (2s. 8d.)
- No. 20.—A Study of Efficiency in Fine Linen Weaving, by H. C. Weston. (1922.) 1s. 6d. (1s. 7d.)
- No. 21.—Atmospheric Conditions in Cotton Weaving, by S. Wyatt. (1923.) 2s. (2s. 1d.)
- No. 37.—Fan Ventilation in a Humid Weaving Shed. An Experiment carried out for the Departmental Committee on Humidity in Cotton Weaving, by S. Wyatt, assisted by J. A. Fraser and F. G. L. Stock. (1926.) 1s. 9d. (1s. 10d.)
- No. 39.—The Relation of Atmospheric Conditions to the Working Capacity and the Accident Rate of Miners, by H. M. Vernon and T. Bedford, assisted by C. G. Warner. (1927.) 1s. 3d. (1s. 4d.)
- No. 46.—A Physiological Investigation of the Radiant Heating in Various Buildings, by H. M. Vernon and M. D. Vernon, assisted by I. Lorrain-Smith. (1928.) 2s. (2s. 2d.)
- No. 48.—Artificial Humidification in the Cotton Weaving Industry. Its Effect upon the Sickness Rates of Weaving Operatives, by A. Bradford Hill. (1927.) 2s. 6d. (2s. 8d.)
- No. 58.—A Study of Heating and Ventilation in Schools, by H. M. Vernon and T. Bedford, assisted by C. G. Warner. (1930.) 2s. 6d. (2s. 8d.)
- No. 59.—Sickness amongst Operatives in Lancashire Cotton Spinning Mills, by A. Bradford Hill. (1930.) 1s. 6d. (1s. 8d.)
- No. 60.—The Atmospheric Conditions in Pithead Baths, by H. M. Vernon and T. Bedford (assisted by C. G. Warner). (1930.) 9d. (10d.)
- No. 76.—The Warmth Factor in Comfort at Work, by T. Bedford. (1936.) 2s. (2s. 2d.)

*References to atmospheric conditions also occur in Reports Nos. 1, 5, 22, 24, 51.*

**(v). Vision and Lighting**

- The Relation between Illumination and Efficiency in Fine Work (Typesetting by Hand), by H. C. Weston and A. K. Taylor. Joint Report of the Industrial Fatigue Research Board and the Illumination Research Committee. (1926.) 6d. (7d.)
- The Effect of Different Systems of Lighting on Output and Accuracy in Fine Work (Typesetting by Hand), by H. C. Weston and A. K. Taylor. Joint Report of the Industrial Fatigue Research Board and the Illumination Research Committee. (1928.) 4d. (5d.)
- The Relation between Illumination and Industrial Efficiency—The Effect of Size of Work. Joint Report of the Industrial Health Research Board and the Illumination Research Committee. (1935.) 4d. (5d.)
- The Effect of Lighting on Efficiency in Rough Work, by S. Adams. Joint Report of the Industrial Health Research Board and the Illumination Research Committee. (1935.) 4d. (5d.)
- No. 40.—The Effect of Eyestrain on the Output of Linkers in the Hosiery Industry, by H. C. Weston and S. Adams. (1927.) 1s. (1s. 1d.)
- No. 49.—On the Relief of Eyestrain amongst Persons performing very fine Work, by H. C. Weston and S. Adams. (1928.) 1s. 3d. (1s. 4d.)
- No. 57.—Further Experiments on the Use of Special Spectacles in very fine Processes, by H. C. Weston and S. Adams. (1929.) 1s. 3d. (1s. 4d.)
- No. 81.—The Effects of Conditions of Artificial Lighting on the Performance of Worsted Weavers, by H. C. Weston. (1937.)
- References to vision or lighting also occur in Reports Nos. 9, 20, 23.*

**(vi). Vocational Guidance and Selection**

- No. 12.—Vocational Guidance (a Review of the Literature), by B. Muscio (1921.) 1s. (1s. 1d.)
- No. 16.—Three Studies in Vocational Selection, by B. Muscio and E. Farmer. (1922.) 1s. 6d. (1s. 8d.)
- No. 31.—Performance Tests of Intelligence, by F. Gaw. (1925.) 2s. 6d. (2s. 8d.)
- No. 33.—A Study in Vocational Guidance, by F. Gaw, L. Ramsey, M. Smith and W. Spielman, under the general direction of Cyril Burt. (1926.) 4s. (4s. 2d.)
- No. 43.—A Study of Telegraphists' Cramp, by M. Smith, M. Culpin and E. Farmer. (1927.) 1s. 6d. (1s. 7d.)
- No. 53.—The Use of Performance Tests of Intelligence in Vocational Guidance, by F. M. Earle, M. Milner and Others. (1929.) 2s. 6d. (2s. 8d.)
- No. 55.—A Study of Personal Qualities in Accident Proneness and Proficiency, by E. Farmer and E. G. Chambers. (1929.) 3s. (3s. 2d.)
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- No. 74.—The Prognostic Value of Some Psychological Tests, by E. Farmer and E. G. Chambers. 9d. (10d.)
- No. 78.—A Borstal Experiment in Vocational Guidance, by Alec Rodger. (1937.) 9d. (11d.)
- References to vocational selection also occur in Report No. 64.*

**(vii). Time and Movement Study, Methods of Work**

- No. 3.—A Study of Improved Methods in an Iron Foundry, by C. S. Myers. (1919.) 2d. (3d.)

- No. 7.—Individual Differences in Output in the Cotton Industry, by S. Wyatt. (1920.) 6d. (7d.)
- No. 8.—Some Observations on Bobbin Winding, by S. Wyatt and H. C. Weston. (1920.) 1s. 6d. (1s. 7d.)
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- No. 15.—Motion Study in Metal Polishing, by E. Farmer. (1921.) 2s. (2s. 1d.)
- No. 17.—An Analysis of the Individual Differences in the Output of Silk-Weavers, by P. M. Elton. (1922.) 1s. 6d. (1s. 7d.)
- No. 22.—Some Studies in the Laundry Trade, by May Smith. (1922.) 2s. 6d. (2s. 8d.)
- No. 23.—Variations in Efficiency in Cotton Weaving, by S. Wyatt. (1923.) 3s. (3s. 2d.)
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- No. 72.—Incentives: Some Experimental Studies, by C. A. Mace. (1935.) 1s. (1s. 2d.)
- No. 77.—Fatigue and Boredom in Repetitive Work by S. Wyatt and J. N. Langdon (assisted by F. G. L. Stock). (1937.) 1s. 3d. (1s. 5d.)

## (viii). Posture and Physique

- No. 29.—The Effects of Posture and Rest in Muscular Work, by E. M. Bedale and H. M. Vernon. (1924.) 2s. 6d. (2s. 8d.)
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- No. 44.—The Physique of Women in Industry (A Contribution towards the Determination of the Optimum Load), by E. P. Cathcart, E. M. Bedale, C. Blair, K. Macleod and E. Weatherhead, with a special section by S. G. Overton. (1927.) 5s. (5s. 2d.)
- No. 50.—The Physiological Cost of the Muscular Movements involved in Barrow Work, by G. P. Crowden. (1928.) 1s. (1s. 1d.)
- No. 71.—The Physique of Man in Industry, by E. P. Cathcart, D. E. R. Hughes, and J. G. Chalmers. (1935.) 1s. 3d. (1s. 5d.)
- References to posture, etc., occur also in Reports Nos. 15 and 16.*

## (ix). Sickness and Absenteeism

- No. 51.—A Study of Absenteeism in a Group of Ten Collieries, by H. M. Vernon and T. Bedford (assisted by C. G. Warner). (1928.) 2s. 6d. (2s. 8d.)
- No. 54.—An Investigation into the Sickness Experience of Printers (with special reference to the Incidence of Tuberculosis), by A. Bradford Hill. (1929.) 4s. 6d. (4s. 8d.)
- No. 62.—Two Studies of Absenteeism in Coal Mines, by H. M. Vernon and T. Bedford. 1s. (1s. 1d.)
- No. 75.—Sickness Absence and Labour Wastage. Part I, by May Smith and M. A. Leiper. Part II, by Major Greenwood and May Smith. 1s. 3d. (1s. 5d.)
- No. 79.—An Investigation into the Sickness Experience of London Transport Workers, with special reference to Digestive Disturbances, by A. Bradford Hill. (1937.) 6d. (7d.)

## (x). Miscellaneous

- No. 10.—Preliminary Notes on the Boot and Shoe Industry, by J. Loveday and S. H. Munro. (1920.) 1s. 6d. (1s. 7d.)

- No. 13.—A Statistical Study of Labour Turnover in Munition and other Factories, by G. M. Broughton, E. H. Newbold, and E. C. Allen. (1921.) 3s. (3s. 2d.)
- No. 27.—Results of Investigation in certain Industries. (1924.) 6d. (7d.)
- No. 45.—Two Contributions to the Experimental Study of the Menstrual Cycle. I.—Its Influence on Mental and Muscular Efficiency by S. C. M. Sowton and C. S. Myers. II.—Its Relation to General Functional Activity, by E. M. Bedale. (1928.) 2s. 6d. (2s. 8d.)
- No. 65.—Two Studies in the Psychological Effects of Noise. I.—Psychological Experiments on the Effects of Noise, by K. G. Pollock and F. C. Bartlett. II.—The Effect of Noise on the Performance of Weavers, by H. C. Weston and S. Adams. (1932.) 1s. 3d. (1s. 5d.)
- No. 70.—The Performance of Weavers under Varying Conditions of Noise, by H. C. Weston and S. Adams. (1935.) 6d. (7d.)
- No. 80.—Toxicity of Industrial Organic Solvents. Summaries of Published Work. Compiled by Ethel Browning under the direction of the Committee on The Toxicity of Industrial Solvents. 7s. 6d. (8s.)

### REPORTS CLASSIFIED ACCORDING TO INDUSTRY

NOTE.—Most of the reports in the following list deal exclusively with the industries under which they are placed. In certain instances, however, reports have been prepared on some general subject, but yet make sufficient reference to a particular industry to justify inclusion under the appropriate heading. These reports are distinguished by an \*. Reports which have no application to particular industries are not included in this section.

#### A.—MINING INDUSTRY

- No. 39.—The Relation of Atmospheric Conditions to the Working Capacity and Accident Rates of Miners. 1s. 3d. (1s. 4d.)
- No. 51.—A Study of Absenteeism in a Group of Ten Collieries. 2s. 6d. (2s. 8d.)
- No. 60.—The Atmospheric Conditions in Pithead Baths. 9d. (10d.)
- No. 62.—Two Studies of Absenteeism in Coal Mines. 1s. (1s. 1d.)

#### B.—METAL AND ENGINEERING INDUSTRIES

- No. 1.—The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture. 6d. (7d.)
- No. 2.—The Output of Women Workers in Relation to Hours of Work in Shell-making. 6d. (7d.)
- No. 3.—A Study of Improved Methods in an Iron Foundry. 2d. (3d.)
- No. 5.—Fatigue and Efficiency in the Iron and Steel Industry. 3s. (3s. 2d.)
- \*No. 6.—The Speed of Adaptation to Altered Hours of Work. 1s. (1s. 1d.)
- No. 15.—Motion Study in Metal Polishing. 2s. (2s. 1d.)

#### C.—TEXTILE INDUSTRIES

- No. 7.—Individual Differences in Output in the Cotton Industry. 6d. (7d.)
- No. 8.—Some Observations on Bobbin Winding. 1s. 6d. (1s. 7d.)
- No. 9.—A Study of Output in Silk Weaving during the Winter Months. 2s. 6d. (2s. 8d.)
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2003-04

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