Fifth Annual report of the Industrial Fatigue Research Board : to 31st December 1924.

Contributors

Great Britain. Industrial Fatigue Research Board.
Medical Research Council (Great Britain)

Publication/Creation

London : H.M.S.O., 1925.

Persistent URL

https://wellcomecollection.org/works/cam2jauw

License and attribution

This work has been identified as being free of known restrictions under copyright law, including all related and neighbouring rights and is being made available under the Creative Commons, Public Domain Mark.

You can copy, modify, distribute and perform the work, even for commercial purposes, without asking permission.

wellcome collection

Wellcome Collection
183 Euston Road
London NW1 2BE UK
T +44 (0)20 7611 8722
E library@wellcomecollection.org
https://wellcomecollection.org

MEDICAL RESEARCH COUNCIL.

FIFTH ANNUAL REPORT

OF THE

INDUSTRIAL FATIGUE RESEARCH BOARD

TO

31st DECEMBER, 1924

(INCLUDING PERSONAL CONTRIBUTIONS FROM INVESTIGATORS).

LONDON:

Printed and Published by His Majesty's Stationery Office, and to be purchased at any of the addresses shown on back of cover.

1925.

Price 1s. 9d. *Net.*

ARY
Collections
P
3968

MEDICAL RESEARCH COUNCIL.

FIFTH ANNUAL REPORT

OF THE

INDUSTRIAL FATIGUE RESEARCH BOARD

TO

31st DECEMBER, 1924

(INCLUDING PERSONAL CONTRIBUTIONS FROM INVESTIGATORS).

LONDON:

Printed and Published by His Majesty's Stationery Office, and to be purchased at any of the addresses shown on back of cover.

1925.

Price 1*s.* 9*d. Net.*

THE BOARD.

The Right Hon. WILLIAM GRAHAM, LL.B., M.P. (Member of the Medical Research Council).—*Chairman.*

R. R. BANNATYNE, C.B. (Assistant Secretary, Home Office).

C. J. BOND, C.M.G., F.R.C.S.

W. L. HICHENS (Chairman, Messrs. Cammell, Laird & Co., Ltd.).

C. S. MYERS, C.B.E., M.D., F.R.S. (Director of the National Institute of Industrial Psychology).

Sir JOSEPH PETAVEL, K.B.E., D.Sc., F.R.S. (Director of the National Physical Laboratory).

ARTHUR PUGH, J.P. (General Secretary, Iron and Steel Trades Confederation).

Sir W. PETER RYLANDS (Managing Director, Messrs. Rylands Bros., Ltd.).

Sir CHARLES SHERRINGTON, O.M., G.B.E., Sc.D., Pres.R.S. (Professor of Physiology, University of Oxford).

E. H. STARLING, C.M.G., F.R.S. (Foulerton Research Professor, Royal Society).

MONA WILSON, J.P.

D. R. WILSON, M.A.—*Secretary*

TERMS OF REFERENCE.

To suggest problems for investigation, and to advise upon or carry out schemes of research referred to them from time to time by the Medical Research Council, undertaken to promote better knowledge of the relations of hours of labour and of other conditions of employment, including methods of work, to functions of the human body, having regard both to the preservation of health among the workers and to industrial efficiency; and to take steps to secure the co-operation of industries in the fullest practical application of the results of this research work to the needs of industry.

OFFICES:

15, York Buildings, Adelphi, London, W.C.2.

FIFTH ANNUAL REPORT
of the
INDUSTRIAL FATIGUE RESEARCH BOARD
to
31st DECEMBER, 1924.

CONTENTS.

PART I.—REPORT OF THE BOARD.

PART II.—PERSONAL CONTRIBUTIONS FROM INVESTIGATORS.

(17133) Wt. 25501/457 1,125 5/25 Harrow G.25 A 2

PART I.—REPORT OF THE BOARD.

1. Introduction.

The Industrial Fatigue Research Board beg leave to submit their Fifth Annual Report for the year ending 31st December, 1924.

The industrial depression, the effects of which on the Board's work were described in their previous Annual Report, has continued with little alleviation through the year now to be reviewed, and has again impelled them to devote their resources to problems for the study of which uniformity and normality in industrial conditions are not wholly necessary.

A notable feature of the year has been the increase in the number of applications received from Government Departments and Industrial Associations for assistance in solving specific problems of immediate practical importance ; the more important of these are briefly described on p. 13.

2. Organisation.

During the year reviewed the Board made representation to the Medical Research Council that the time had now arrived when the right framing of their policy would be greatly assisted by strengthening their constitution on the industrial side. They are glad to report that in October last Sir W. Peter Rylands (Managing Director of Rylands Bros., Ltd.) and Mr. Arthur Pugh, J.P., both accepted the invitation of the Medical Research Council to become members.

The Chairman of the Board, who was compelled by his ministerial duties to withdraw from active participation in their proceedings, has now found it possible to return. The Board are indebted to Mr. C. J. Bond for consenting to act as deputy chairman during his absence.

Scientific Committees.

The scientific criticism of the Board's work and the initiation and supervision of the various laboratory researches have remained in the hands of three Committees.

Industrial Health Statistics.—The Board have had the advantage of the criticism and advice of this Committee in all their investigations which have required to any extent the use of statistics or statistical method. Whilst the Committee takes an important part in the Board's activities, its work extends into a field outside their terms of reference and embraces many subjects of medical or quasi-medical interest. Amongst these may be quoted the inquiries into sickness incidence among miners and quarrymen undertaken in consultation with the Mines Department, into the application of tests of physical efficiency conducted by Dr. Lucy Cripps (now Lady Hopkins), into the occupational incidence of cancer conducted by Dr. John

Brownlee and Professor E. L. Collis, and into the effects of migration from country to industrial cities with special reference to phthisis incidence conducted by Mr. A. B. Hill. The results of these investigations will be published as reports of the Medical Research Council, but having regard to their industrial interest, mention of them is here made.

It often happens, especially in social investigations, that some of the qualities examined can only be classified in two or more broad groups, so that statistical analysis involves variables to which numerical values cannot be given. A technical study has been completed by Miss Newbold for the Committee with the object of assessing the measure of confidence that can be put in correlational results based on data of this kind.

The constitution of the Committee has been strengthened by the addition of Dr. T. H. C. Stevenson of the General Register Office.

Physiology of Muscular Work.—The Committee has collaborated closely with the Board in regard to an important part of their functions, namely the investigation of heavy manual labour, and has also initiated and supervised the researches specified on p. 17. The Board wish to record their appreciation of the valuable work done for this Committee by Dr. B. A. McSwiney, who resigned the Secretaryship as from the end of last year.

The Board with great regret have to report the death at the age of 32 of Mr. Hartley Lupton, B.Sc., after a brief illness. Mr. Lupton had for three years worked under the direction of Professor A. V. Hill for the Committee on Physiology of Muscular Work, and the recent progress in the application of the modern physiology of muscle to the practical life of man is largely due to his work.

Industrial Psychology.—A large part of the work carried out by the Board, dealing with light repetitive work and accident causation, has fallen naturally within the scope of this Committee, which is also responsible for the general supervision of the various researches on psychological subjects (p. 20).

Special Committees.

The special Committees appointed to review periodically the progress of investigations from different scientific aspects have again proved of great assistance to the Board. They are now five in number, dealing respectively with Post Office Work, Hours of Work, Accident Causation, Design of Machinery, and Physiology of Ventilation. The Board are glad to report that the Post Office have acceded to their request that Colonel H. V. Prynne, C.B.E., D.S.O., Chief Medical Officer, and Mr. John Lee, C.B.E., Controller of the Central Telegraph Office, should join the Committee on Post Office Work appointed to supervise the investigation of Telegraphists' Cramp (p. 15), which has been further

strengthened by the addition of Dr. Henry Head, F.R.S.; Professor E. L. Collis, M.D., has been nominated by the Department of Mines to join the Committee on Physiology of Ventilation in respect of the investigation of Atmospheric Conditions in Mining (p. 16), and Sir Gerald Bellhouse, C.B.E., (H.M. Chief Inspector of Factories) has consented to become a member of the Committee on Hours of Work. To ensure that the psychological aspects of Machine Design are not overlooked, the secretaryship of the supervising Committee has been offered to and accepted by Dr. G. H. Miles, Assistant Director of the National Institute of Industrial Psychology. The Committee on Women's Employments, which acts as an advisory body to the Board on problems specially affecting women workers, is now being reconstituted and strengthened.

A list of the principal Committees is given in the Appendix (p. 29).

3. Investigations and Researches.

The present work of the Board may be regarded as falling into three categories :—

A.—Investigations of particular problems of wide industrial importance.

B.—Studies of specific problems submitted by Government Departments or Industrial Associations.

C.—Experimental researches undertaken in university and other laboratories.

The following is an account of the principal investigations in each category completed during the past year or still in progress.

A. Particular Problems of Wide Industrial Importance.

(1) *Hours of Labour, etc.*—For the successful exploration of the wider aspects of the effects of hours of labour of different duration and distribution, prolonged uniformity in the conditions to be compared is necessary. The year now reviewed, like its predecessor, has been notable for short time and for frequent alterations in working hours made to meet the fluctuations in conditions of trade, and has not been favourable to the study of these questions. Investigation has therefore again been chiefly directed to the effects of rest-pauses and of changes of occupation within the working spell itself, rather than to questions concerned with weekly or daily total hours.

The Board have already pointed out that rest-pauses must be regarded from different points of view according to the type of occupation. In heavy muscular work, the primary effect to be considered is physiological fatigue, due to definite chemical changes in the body ; in most light occupations, on the other hand, the effects are mental rather than bodily, relating chiefly to such feelings as those of monotony and boredom. In both types temporary cessation from the work usually brings about rapid and complete recovery.

Rest-pauses in the muscular type of work have been studied by Dr. H. M. Vernon (assisted by Mr. T. Bedford) under laboratory conditions. The results show consistently that where maximal effort is repeatedly exerted, marked benefit results from the interpolation of short rest-pauses at short intervals, especially if the posture is changed during the rest. The optimum duration and position of pauses for this type of work remain to be determined, and this task will be greatly facilitated by the recent researches of Professor A. V. Hill and others (see p. 17). The Board have decided to explore the possibility of applying these laboratory results to industrial practice, and as a first step have invited Professor Hill to initiate the study of some common types of industrial work under laboratory conditions. Arrangements have now been made for some preliminary experiments to be conducted by Mr. G. P. Crowden, B.Sc., at University College, London.

Considerable progress has been made in the study of the effects of rest-pauses in light repetition work. Reports already issued by the Board have confirmed previous work in showing that under the controlled conditions of the laboratory the interpolation of rest-pauses in repetitive tasks has been almost always followed by a distinct improvement in the quantity and quality of the work. The study of rest-pauses under practical conditions, however, is complicated by the fact that most industrial occupations do not involve truly continuous work throughout the spell. Usually, occasional opportunities for rest are available and even in processes which to an onlooker seem to be carried out without a break, close observation has shown that pauses, either voluntary or imposed, are in fact taken by the operatives concerned. The intensive conditions obtaining in the laboratory are therefore clearly not reproduced in industry, and the startling increase in output obtained in many experiments of this type cannot be expected from the interpolation of a rest-pause in an ordinary spell of work in a factory. In short, in estimating the effects of rest-pauses under industrial conditions we are comparing, not discontinuous with continuous work, but work interrupted by a rest of given incidence and duration with work interrupted by unorganised rests, taken sometimes voluntarily by the workers and sometimes imposed on them by technical exigencies.

The previous investigations conducted by the Board have been confined to a comparison of output during periods before and after the introduction of rest-pauses, and have therefore been subject to the objection inherent in all investigations based on past records, namely, the difficulty of ensuring that other working conditions were identical over the periods compared. Even here, however, indications have emerged that a short rest-pause interpolated in a spell of 4½ or 5 hours was usually followed by a small but genuine improvement of the order of 5 to 10 per cent. During the year under review, opportunities have arisen of testing these conclusions more exactly, through facilities offered in four factories

for the current introduction of rest-pauses on an experimental basis. The results of this investigation, which was carried out by Mr. S. Wyatt, with the assistance of Mr. James Fraser, strongly confirm those of the previous studies, in suggesting that in light repetitive work the introduction of rest-pauses into the spell of work will result in increased output, notwithstanding the shorter time spent in actual work. An incidental point of some interest is the consistent indication that the anticipation of the rest-pause has often a beneficial effect ; that is to say, an increase of output occurs throughout the spell and not only during the part of the spell following them.

The Board, then, are of opinion that in many types of work, organised rest-pauses will be found beneficial. Having regard to the possible wide-reaching effects of the practice, they have invited Mr. Wyatt to prepare a summary of past experience in this matter, and this is now in course of publication.

Closely allied to the question of rest-pauses, involving complete cessation from work, is the effect of change from one activity to another during the spell. Here, again, results obtained during the year reviewed are confirmatory of others previously secured, in showing that complete specialisation in a given operation may often be less desirable than a moderate degree of change in occupation during the spell. In this respect, there is clearly an optimum state, when the loss of " incitement " or " warming up " characteristic of the initial stages of all types of work is balanced by the feeling of relief from one type of operation performed continuously. Further investigation is required, however, before definite conclusions on this point can be drawn.

In addition to rest-pauses, hours of work have been investigated by the Board from two other aspects. In the first place an opportunity has occurred for comparing the effects of dispensing with Saturday work, whilst increasing the period of employment on other days, with the ordinary system of working 5½ days a week. At the suggestion of Mr. Farmer, arrangements have been made with a firm for keeping special records for the departments concerned and when the data are collected it is hoped that some comparison between the two systems may be possible.

Secondly, in certain women's occupations a comparative study of shifts of equal length but extending over different hours of the day has been begun. Facilities for investigation have been obtained in several factories where an opportunity for making this comparison exists, and data are now being collected by Miss M. Vernon, working under the direction of Miss May Smith.

(2) *Accident Causation.*—This investigation has proceeded on the lines described in the Board's last Annual Report. For an important part of it special facilities have been obtained at H.M. Dockyard, Portsmouth, by the kind consent of the Admiral Superintendent.

On the statistical side, which is mainly in the hands of Miss E. M. Newbold, working for the Committee on Industrial Health Statistics, the analysis of the accident records specially kept for the Board through the courtesy of several large firms in different industries, is very nearly complete. The general results confirm those derived from an analysis of the first few samples examined as reported in the Board's Fourth Annual Report, and the main tendencies shown may be summarised as follows :—

(*a*) On the whole it appears that a high accident average in a department is usually traceable to a relatively small proportion of those employed, and that the distribution of accidents, even in the groups where apparently the conditions were most alike for all, is far from that to be expected on the basis of chance. It is difficult in mass statistics of this kind to distinguish between the personal tendency and outside factors, whilst the possibility in some cases of reluctance to report trivial accidents has also to be borne in mind ; there are, however, many indications which point to the part played by the personal factor being a large one.

(*b*) There is no evidence that the occurrence of one accident tends *per se* to increase the liability to another.

(*c*) A universal tendency appears for these small accidents to be more frequent among the younger workers, and this does not appear to be entirely due to the fact that the older workers have had longer experience of the particular occupation.

(*d*) There is a slight but consistent association between accidents and minor ailments reported at the ambulance room.

(*e*) Night and day work have up to now shown no difference as regards the number or distribution of accidents, and so far as a comparison is possible, all the tendencies mentioned above are alike for both men and women.

It is clear *a priori*, and in the course of the present work the point has continually emerged, that the scope of the mass examination of the sort of material dealt with here is limited, and that a study of the individual factor in accident causation calls rather for more work along the lines of individual study and experimental psychology (of the kind adopted in the second part of the investigation), than for an extension of the statistical side of the work. This limitation is not meant, however, to apply to the use of accident statistics of this kind by individual factories, where the necessary details relating to the conditions of work and to the workers are either known or can be readily ascertained. Careful study of such records in different departments, either along the lines followed in this investigation or in other fuller ways which may be possible in individual cases, would probably often define more closely the profitable field of preventive measures.

Arrangements have also been made by Mr. Farmer for the collection of the sickness, accident, and "exposure to risk" records of 16,000 dockyard workers for a complete year, with the primary object of determining how far the incidence of minor accidents is related to that of major accidents. The analysis of these records is now in progress.

On the psychological side of the investigation, tests applied during 1923 by Mr. Farmer (assisted by Mr. E. G. Chambers) to selected factory workers have been repeated on the same groups with a view to establishing the validity of the tests employed. The new results showed consistency between the performances on both occasions. The same investigators have applied selected psychological tests to 150 apprentices in H.M. Dockyard, Portsmouth, and the results were consistent with those obtained with the factory group already mentioned. It is intended that the results of these tests shall eventually be correlated with the accident history of the subjects concerned. So far as the inquiry has proceeded, there are again clear indications of the possibility of detecting persons specially susceptible to accidents, before they are actually exposed to the risk of incurring them. Special facilities have recently been granted by the Naval Authorities at Whale Island and by the Royal Air Force at Halton for testing groups of men under training. It is hoped that the results obtained by testing the large number of subjects thus offered, when co-ordinated with the results obtained from other sources, will throw further light on various aspects of accident susceptibility. The special apparatus used in this part of the investigation has been designed and constructed by Dr. E. H. J. Schuster, and the Board desire to acknowledge the valuable assistance received from him in this respect.

On the theoretical side, research on the factors underlying accuracy of movement has been conducted at the Psychological Laboratory, University of Cambridge, by Miss M. Vernon and Dr. Teruoka working under the direction of Mr. F. C. Bartlett. This research, which involved continuous work over spells of four hours, is not confirmatory of Professor Muscio's tentative conclusion that rate of work is more important than fatigue in diminishing accuracy of movement. It is hoped to continue this work at a later date.

(3) *Design of Machinery.*—The Board in their Fourth Annual Report have stated their reasons for thinking that an investigation into the design of certain machines from the point of view of easy operation might yield fruitful results, and they were then glad to report that the Department of Scientific and Industrial Research had consented to co-operate with the Medical Research Council in assuming responsibility for a substantial part of the cost and in appointing members to the Committee formed to supervise the investigation.

Work has proceeded mainly in three directions. First, Mr. L. A. Legros and Mr. H. C. Weston have made a survey of

several industries and, in consultation with the different Research Associations, have endeavoured to discover how far machines in common use fall short of the physical or physiological requirements of the operator. Although in most instances no failing in this respect could be detected, several machines have in fact been found, the operation of which would appear to be facilitated by some alteration in design, often of a trifling nature. Secondly, typical machines have been selected and the indicated alteration actually carried out. The effects of the alteration are now being estimated through comparison of the performance of the machines before and after it was carried out. Lastly, the energetics of muscle have been studied by physiological methods under the general direction of Professor E. P. Cathcart at Glasgow University. An investigation by Dr. R. C. Garry of the maximum static pull and push at different angles has already yielded consistent results, and the research is now being extended by Dr. David Hynd so as to cover dynamic effort under similar conditions. For this purpose a dynamometer, which records the force exerted by the subject during motion throughout the whole cycle (whether continuous rotary motion or reciprocating, and for any position of the axis relatively to the stance of the subject), has been specially designed by Mr. Legros.

(4) *Physiology of Ventilation.*—The reasons for initiating investigation in this subject have been already fully explained by the Board in their Fourth Annual Report. During the year under review, Dr. H. M. Vernon and Mr. T. Bedford (assisted by Mr. C. G. Warner) have made systematic studies of various systems already installed in factories, in order to discover how far these conform to physiological requirements. One such system, which appears to be especially efficient, has been subjected to extensive observation and experiment in winter and summer, and continuous records are being taken over a whole year, with the object of obtaining some standard with which other systems may be compared. Data relating to lost time from sickness also have been collected, and indicate in certain instances that there is a considerable increase of sickness under the adverse conditions of ventilation there experienced.

In their observations the investigators have made extensive use of the kata-thermometer, and by systematically recording their sensations of air movement, before making the actual observations on cooling power, have found a high degree of correspondence between them.

In addition, the effects of oscillations in air movement have been explored by means of the " hot-wire anemometer " (briefly described in the Board's Fourth Annual Report), and those of oscillations in air temperature by a delicate thermopile invented by Mr. J. J. Manley of Oxford and Dr. Vernon. An increase in the oscillations of air movement has been found to cause a distinct increase in the subjective sensations of freshness, and

a simple method of increasing these oscillations, depending on intermittency in the running of the fan, has been tried. These observations, if fully confirmed in other fan-ventilated rooms, may prove of considerable practical importance. At the Daubeny Laboratory, Oxford, some time has also been devoted to recalibrating the kata-thermometer by the "whirling arm" method. A table of corrections has now been constructed.

The merits of different conditions of fan-ventilation in improving the atmospheric conditions are being studied by Mr. Wyatt, and arrangements have been made in co-operation with the Home Office Committee on Humidity in Cotton Weaving (see p. 13) to extend this work so as to include experimental installation of ventilating systems in selected weaving sheds during the summer of 1925.

(5) *Rate of Improvement in Industry.*—The speed with which skill is acquired in industrial occupations is not only of great theoretical interest but has clearly a very important bearing on the well-being of the individual worker and on productive efficiency. By the collection of reliable output data over a number of years it would be possible to trace the improvement in various occupations at various ages and with the two sexes, and the information so obtained could eventually be used for the following purposes :—

(*a*) classification of learners into different types with a view to studying the reasons for these differences ;

(*b*) classification of occupations according to the time required to attain proficiency ;

(*c*) determination of the most suitable age for entering a given occupation ;

(*d*) determination of the time to be allowed before deciding whether a beginner will or will not eventually become proficient ;

(*e*) determination of the relative importance of speed of improvement with the standard ultimately reached, e.g., whether in a given occupation it is better to employ workers who quickly attain but never surpass a certain proficiency, or those who are slower at learning but ultimately reach a higher standard.

Some years must necessarily elapse before sufficient data can accumulate to give even a partial answer to these questions. The Board therefore have thought it desirable to arrange at once for records of improvement to be kept for selected processes whenever suitable facilities can be found.

Concurrently with these observations, the theoretical side of the subject will be studied to some extent in connection with the research on muscular skill, conducted by Professor T. H. Pear and Miss I. Burnett.

B. Specific Problems submitted by Government Departments or Industrial Associations.

During the year under review, the number of applications for assistance in solving problems of immediate practical importance has largely increased. The more important of these may be now described.

(1) *Sickness in Cotton Weaving Sheds.*—Artificial introduction of moisture into the air of cotton weaving sheds in which certain kinds of cloth are woven has for many years been the subject of controversy in the industry. In view of the continuous objection of the operatives to the practice, especially during the hotter months of the year, the use of artificial humidity has long been limited and controlled by statutory requirements, the existing regulations (which allow artificial humidification within certain limits) having been made on 21st December, 1911, under the Cotton Cloth Factories Act of that year on the Report of a Committee of which Sir Hamilton Freer-Smith, R.N., C.S.I., was Chairman.

For a number of years a demand has been made by the operatives for the total abolition of artificial humidification as being injurious to health, and has been opposed by the employers on the ground that it is essential to manufacture. The question was again investigated by Sir H. Freer-Smith in 1920, but no settlement was arrived at, one of the principal difficulties being that no definite evidence was forthcoming to show that humidification within the limits allowed is in fact injurious to health, or that there is more sickness amongst weavers in humid sheds than amongst those in dry sheds. Finally, in view of the Factories Bill which was recently introduced, further conferences have been held between representatives of the Home Office, employers and operatives, with a view to securing agreement as to the limits within which artificial humidification should be allowed. These conferences, however, also failed to come to an agreement, and at their request the Secretary of State in November last appointed a Departmental Committee under the Chairmanship of Mr. John Jackson, H.M. Deputy Chief Inspector of Factories, "to consider and report whether any, and, if so, what modifications of the existing statutory regulations governing the use of artificial humidity in cotton cloth factories are desirable and practicable." On the recommendation of this Committee, the Home Office approached the Medical Research Council with the request that the subject of sickness amongst weavers in the Cotton Industry should be investigated by the Board.

As stated in their previous reports the Board, and more particularly the Committee on Industrial Health Statistics, gave some attention to this subject in 1922. A tentative scheme of inquiry was in fact drawn up, but owing to the abnormal industrial conditions prevailing, the matter was not then further pursued

and has since been left in abeyance. The best method of investigating this difficult subject is now being closely considered by a special Committee composed of representatives of the Committee on Industrial Health Statistics and the Departmental Committee on Humidity (see p. 30); and it is hoped that with the co-operation of the industry and of the Approved Societies concerned, definite information may be eventually secured.

(2) *Weight Lifting and Carrying.*—As is stated elsewhere, one investigation carried out during the year reviewed has dealt with the subject of weight carrying. This, however, has been confined to a comparison of different methods of carrying, and hardly touches on the question of the maximum load that can be carried without injury or discomfort. A request that the investigation should be continued so as to embrace this second point has been received by the Medical Research Council from the Home Office. It is pointed out that the lifting or carrying of weights by women and girls has long been regarded as a matter requiring regulation, but that while it has been possible to include provisions on the subject in codes of regulations made for dangerous or unhealthy industries, there has hitherto been no general or specific provision in the Factory Acts in regard to it. A proposal to rectify this omission appeared in the Factories Bill, 1924, Clause 51, which ran as follows :—

> "(1) A woman or young person shall not be employed to lift, carry or move any weight so heavy as to be likely to cause injury to such woman or young person.
>
> " (2) The Secretary of State may make special Orders prescribing the maximum weights which may be lifted, carried or moved by women or young person of any age in any class or description of factories, or when engaged in any process."

Having regard therefore to the probability of definite administrative powers being conferred on the Secretary of State by Parliament in the near future, the Home Office have requested that the actual load that can be lifted or carried by women and young workers under industrial conditions without injury or discomfort should be the subject of scientific investigation, and suggest that the results of such an inquiry would afford them valuable guidance in the administration of the new powers contemplated in the Bill.

The Board are glad to report that Professor Cathcart has consented to direct the continuation of the investigation which will be carried out on the lines described, by Miss E. M. Bedale, Miss C. A. R. Blair, M.B., and Miss Weatherhead. It is proposed that the investigation should begin with inquiry in the following three directions :—

> (*i*) The collection of statistical data, regarding the height, weight and muscular powers of women in different occupations ;

(*ii*) Laboratory experiments under controlled conditions to supplement the exact determinations already made on methods of carrying; and

(*iii*) The making of random observations of the weights now actually carried or lifted in different occupations.

For the third of these the Board are indebted to H.M. Chief Inspector of Factories for authorising part of his staff to participate in the inquiry, and also to Sir Thomas Legge, H.M. Medical Inspector of Factories, for his consent to the part-time collaboration of Miss S. G. Overton, M.B.

(3) *Telegraphists' Cramp.*—In their Fourth Annual Report the Board gave a short account of the position of the investigation into telegraphists' cramp and pointed out that whilst there were certain indications that persons specially susceptible to cramp might eventually be detected before the onset of the disability, the evidence so far adduced was not sufficiently decisive to admit of definite conclusions.

An interim report, embodying the results hitherto obtained and containing suggestions for future lines of work was submitted to the Post Office, and their concurrence has been obtained for the continuance of the investigation, which will again be made by Mr. E. Farmer and Miss May Smith, with the collaboration of Dr. Millais Culpin.

(4) *Illumination.*—As was stated in the Board's Fourth Annual Report, the collaboration of the Medical Research Council was sought by the Department of Scientific and Industrial Research in regard to the constitution and functions of a Committee to investigate problems of lighting. At the request of this Committee, the part-time services of Mr. H. C. Weston were placed at its disposal in January, 1924, and he has since been engaged on the study of the best methods of lighting composing rooms, a subject on which the Committee is being assisted by the Joint Industrial Council for the Printing Trades. The investigation is being extended by him at the National Physical Laboratory so as to embrace trials of various systems under controlled conditions.

(5) *Coloured Inks and Papers.*—The problem of the most effective contrast between coloured papers and inks, which was originally referred to the Board by the Post Office, has for some time been the subject of research by Miss M. Vernon at the University of Cambridge, working under the direction of Mr. F. C. Bartlett. The results hitherto obtained, without being definitely conclusive, suggest that whilst certain combinations are clearly worse than others, colour contrast *per se* is certainly less important than the arrangement of printed matter on the forms. A preliminary report has been submitted to the Post Office with

the suggestion that the tentative conclusions arrived at might suitably be tested by experimental application on a provisional basis.

(6) *Atmospheric Conditions in Mines.*—The Department of Mines, on the recommendation of their Health Advisory Committee, have invited the Board to investigate the relation of atmospheric conditions in coal mines to efficiency and fatigue. It is hoped during the present year to start work on these lines under the direction of Dr. Vernon.

(7) *Efficiency in Typewriting.*—At the request of H.M. Treasury an investigation has been carried out by Miss May Smith into the effects of rubber key caps on typewriting machines. A report on the subject is now in course of preparation.

(8) *Pottery Industry.*—In February, 1924, the National Society of Pottery Workers and their affiliated unions in the industry served on the British Pottery Manufacturers' Federation, as part of their wages demands, a notice to the effect that "on or before 1st January, 1925, all female placers and dippers in the General Earthenware, China and Rock and Jet Trades, shall be dispensed with." The parties to the notice having failed to reach agreement, the matters in dispute were brought before a special meeting of the National Council for the Pottery Industry, who decided to refer the claims of the operatives and employers respectively to a special committee of the Council. The result was that the operatives agreed to withdraw their notice as regards dippers, but pressed for the displacement of placers (both glost and biscuit) on the grounds that the work is unsuitable for women. The National Council, on the advice of their special committee, decided to obtain scientific guidance on the subject and with this in view invited the Board to hold an investigation into the physiological aspects of the question raised by the claim. This invitation was accepted and the Board were fortunate in obtaining the consent of Professor Cathcart to supervise the investigation. The work has now been completed by Miss E. M. Bedale under Professor Cathcart's direction and in consultation with representatives of the industry, and a report on the subject has been submitted to the National Council, and is still under consideration by them.

(9) *Jute Industry.*—In May, 1923, a letter was received from the Jute Trade Board (Great Britain) inquiring whether the Board, if so invited, would be prepared to undertake an investigation into the effects of fatigue in the industry. The Board willingly agreed to afford every assistance in their power, and a preliminary discussion of the matter with the Trade Board and with some of the principal employers and labour organisations followed. The workers were desirous that the investigation should be conducted, but after considerable discussion the Employers' Association

decided that they could not see their way to participate in any inquiry or even to afford facilities for a preliminary survey with a view to disclosing problems which appeared to call for special study, and accordingly no definite request for an inquiry from the Trade Board ever materialised.

The Board cannot but regret this decision on the part of the Jute Spinners and Manufacturers Association, and hope that the question of co-operation may yet be re-considered at some future time.

C. Laboratory Researches.

(*a*) *Researches relating to Muscular Work.*

(1) *The Principles governing Muscular Exercise.*—During the last year a full account has been published, in three papers in the Proceedings of the Royal Society, of the researches which have been carried out during the last three years by Professor A. V. Hill, F.R.S., Mr. Hartley Lupton and Mr. C. N. H. Long.

Of the more recent work on muscle the most fundamental is that relating to the recovery process which occurs after exercise. The discovery of this process was made originally on the isolated muscle of the frog. The clear picture so obtained of the process of recovery was obviously of great importance in connection with the physiology of human muscular work and the present experiments were intended to ascertain the extent to which the principles elucidated in the case of the isolated muscle were directly applicable to man. These experiments have proved far more successful than was originally expected, and the recovery process in man was found to be susceptible of very exact investigation by means of respiratory and chemical measurements.

As was explained in the Board's Fourth Annual Report, the physiological state during and after exercise is determined by the balance between the formation of lactic acid in the muscles, its passage into the blood and its removal by the inspired oxygen.

The extent to which exercise may be undertaken without exhaustion depends upon the speed at which the oxidative recovery process can keep pace with the breakdown process directly associated with muscular effort. Mild effort is followed by a recovery process of quite moderate extent, but severe effort, either of short duration or prolonged, is necessarily followed by extensive reactions in the body by which the *status quo ante* is restored and the muscular system put into a state when it is able to function as before. The chemical processes associated with recovery are known, at any rate in outline, and on the analogy of a storage battery, they represent the recharging of the cell which has been run down by activity. After moderate exercise the recovery process is rapid, but after severe exertion it may take a long time to reach completion. Were it not for this capacity of the body of working, so to speak, on credit and

obtaining the energy to carry out this "re-charge" after the exertion is complete, the human body would not be capable of any except quite moderate effort.

The exact knowledge reached by these investigations of the course and extent of the recovery process in man has led to various results which are fully discussed in the three papers in the Proceedings of the Royal Society referred to, and work is being continued on the same lines to follow up various other points which have arisen. On the more purely physiological side the investigators have had the advantage of the help of Mr. K. Furusawa, who has found that the oxidation occurring in the recovery process from a short period of exercise is one only of carbohydrate, though in prolonged exercise other elements in the food, particularly fat, appear to come either directly or indirectly into play.

They have had also the help of Dr. Katz, Medical Fellow of the National Research Council, U.S.A., who, with Mr. C. N. H. Long, has been studying the case of heart muscle, in an endeavour to find out how far that muscle, which is the fundamental agent in determining the capacity of the body for violent exertion, behaves in a manner similar to ordinary voluntary muscle in its relation of activity to recovery. The heart is rather specially placed, as its blood supply, at any rate in an efficient organ, is much more liberal than that of other muscles, and it seems possible that the heart is not so dependent upon its recovery process for violent exertion (as in severe bodily exercise), but is more able to meet its energy requirements out of its current income of oxygen. The study of heart muscle may prove important, not only in normal individuals in whom it is the determining factor in the capacity for violent and prolonged exertion, but in subjects affected by abnormal cardiac conditions.

In another direction, Mr. C. N. H. Long has been co-operating with Dr Hetzel, of the Medical Unit of University College Hospital, in investigating the case of muscular exercise in diabetic individuals. There seems reason to suppose that muscular exercise in the diabetic may prove to have a definitely beneficial effect if properly controlled. The phenomena of muscular exercise in diabetes are being more fully investigated, both on men and on animals. Many interesting results concerning the chemical processes occurring in the normal body may be obtained by the study of muscular exercise in diabetics.

A further series of experiments has been started by Mr. K. Furusawa on the optimum speed of work. It has been already shown that in one particular process, namely the climbing of a staircase, there is an optimum speed, that is, one at which the requirements of the body for energy and oxygen are less for a given task than at all other speeds. The factors determining the optimum speed appear to be clearly understood, and the investigation now in progress is to confirm and amplify the conclusions reached by Mr. Lupton. The subject has obvious

important applications in reference to the physiology of work in industrial processes. Arrangements have been made, therefore, for tests to be carried out, under practical conditions, of the existence of this optimum speed in such processes as wheeling barrows. There is probably both an optimum speed and an optimum load for this kind of work, and Mr. G. P. Crowden is intending shortly to take up this investigation at University College.

In a recent report Dr. Vernon pointed out the importance of the circulation, during rest pauses, in facilitating recovery from previous work; gentle movement, or massage, during the rest pause greatly helps the circulation in the muscles which were previously working and so leads to greater vigour and freshness in subsequent work. Experiments are being made at University College to determine the speed at which the circulation falls off, from the moment that exercise ends. The stoppage of movement immediately causes a rapid fall in the circulation rate of the blood, which delays the recovery process occurring after severe exercise. It may very well prove to be the case that after hard effort it is better not to stop completely, but to continue the same or another effort at a more moderate speed, in order to facilitate the circulation of the blood and so ensure a more rapid recovery.

The co-ordination of muscular movement and the efficiency with which movements may be performed depend in large degree upon the maintenance of certain postures of the body during the movement. At the present time there is much discussion of the tonic function of various types of muscle, and in this direction it is possible that the pure physiology of muscular movement may prove again to have a considerable effect on the practical case of muscular effort in industrial processes. Attempts are being made in various ways to follow up the scientific side of this problem of the physiology of postural effort in muscles.

(2) *Weight Carrying.*—At the University of Glasgow, under the direction of Professor E. P. Cathcart, M.D., F.R.S., Miss E. M. Bedale has completed her research on Comparative Methods of Weight Carrying and a report on this has lately been published. The results are important as indicating, first, that the different methods studied have a definite order of merit, demanding different expenditures in the chemical exchanges of the body, and secondly, that these " physiological costs " are related to physical causes, particularly to the different degrees to which the body's normal centre of gravity is displaced. The research deals only with methods of carrying, but as already indicated (p. 14), it is now being extended so as to include the determination of the maximum weight of the load that can be carried without discomfort.

(3) *Tests for Physical Fitness.*—Research on physical fitness in health and disease has been continued at Guy's Hospital,

London, by Professor M. S. Pembrey, F.R.S., Dr. J. M. H. Campbell, Dr. G. H. Hunt, Mr. E. C. Warner, Mr. G. O. Mitchell, and Mr. A. T. Powell. A report, in which the various methods of assessing physical fitness are reviewed and the results of some new methods described, is in course of publication by the Medical Research Council.

(4) *Dynamic and Static Effort.*—Reference is made elsewhere to this research which is being conducted at the University of Glasgow in connection with the investigation of the design of machinery (p. 10).

(*b*) *Other Researches.*

(1) *Vocational Selection.*—The preliminary investigation into methods of vocational selection and guidance, which has been carried out under the joint auspices of the Board and the National Institute of Industrial Psychology has now been completed. The work has been conducted for the Board by Miss May Smith, Miss Frances Gaw and Miss L. Baker, and for the Institute by Miss Winifred Spielman, under the general supervision of Dr. Cyril Burt. A full report on the results is now in draft and will shortly be published.

As a preliminary step, an analysis of the occupations taken up by 1,000 children leaving the schools in a London Borough was made, in order to ascertain which were likely to be the commoner occupations involved. The investigation proper, which was limited to the children educated at three schools in the Borough, consisted of an intensive individual study of all the children due to leave the three selected schools in the course of the next twelve months, and was conducted on the following lines :—

(*a*) The homes of the children were visited and the social and economic status of the families noted, together with the occupations of the parents and any information likely to throw light on the hereditary tendency of the children.

(*b*) All available data as to each child's physical condition, school attainments and progress were collected from the teachers and from the school medical inspection records.

(*c*) The mental capacities of each child were tested by the application of certain tests designed to measure (i) his intelligence, as expressed both verbally and in performance ; (ii) his special aptitudes for the commoner occupations, and (iii) his educational attainments, each test being applied by an investigator who had specialised in it. At the same time, the temperamental qualities of the child were assessed during special interviews and by observations made in the course of testing.

(*d*) Finally, the full data obtained for each child were discussed by the investigators, and the vocational recommendations agreed on were forwarded to the School Conference on choice of occupation and to the parent.

It is hoped to follow up the children during the next two or three years, in order to discover how far the results based on the tests applied are satisfactory

Investigation on a more extensive scale is being continued by the National Institute of Industrial Psychology under a grant received from the Carnegie United Kingdom Trust.

The Board desire to offer their thanks to the London County Council Education Authority for permission to examine the schoolchildren, and to all others, especially the teachers in the schools selected, for their assistance and collaboration.

A report by Miss F. Gaw containing full descriptions of non-oral performance tests, with an account of their special uses, is in course of publication.

(2) *Accuracy of Movement.*—Research on the effects of long spells of repetitive work on accuracy of movement has been completed by Miss M. Vernon. The results obtained do not support the conclusion tentatively reached by Professor Muscio in respect of spells of shorter duration, that accuracy of movement is dependent on rate of work rather than on fatigue. Their chief feature is the marked differences in the records of different individuals, indicating that no general deductions can be made from the trend of speed and accuracy in the work of a few observers under experimental conditions. The Board hope to arrange for the continuance of the research in the near future.

(3) *Repetitive Work.*—The special characteristics of work involving repetition of the same short operation (stitching on canvas), and in particular the effects of the system of reward (time or piece rate), have been examined under controlled conditions at the University of Manchester by Miss I. Burnett under the supervision of Professor T. H. Pear. The research has been completed and a report on it is in course of publication.

(4) *Muscular Skill.*—Research on the principles underlying the acquisition of muscular skill (as opposed to mere muscular activity or capacity) has lately been initiated and will be carried out by Professor T. H. Pear and Miss I. Burnett at Manchester University.

Simultaneously with this work, Miss L. C. Baker, working at the University of Cambridge under the supervision of Mr. Bartlett, is attempting an experimental determination of the relation of different types of imagery to the speed of acquisition and the accuracy of control of certain kinds of bodily movement.

(5) *Menstrual Period.*—The psychological study of the effects of menstruation conducted at Cambridge University by Miss S. M. Sowton under the direction of Dr. C. S. Myers has just been completed.

Menstruation has also been studied by Miss Bedale under the direction of Professor Cathcart, and a report based on observations of the basal metabolism and working (muscular) capacity during the period has recently been submitted.

4. External Relations.

Close touch has continued throughout the year with various Government Departments. On the one hand, the Board have been approached in regard to the solution of problems with which their existing organisation appeared qualified to deal; on the other hand they are indebted to several Departments for the provision of valuable facilities for investigation. The Board desire to acknowledge the assistance and advice received from the Admiralty, the Post Office, the Ministry of Labour, the Ministry of Health, and the Home Office, and are especially indebted to H.M. Inspectors of Factories for information supplied by them.

For some parts of the Board's work the Medical Research Council have obtained the co-operation of the Department of Scientific and Industrial Research. For the investigation into machine design, which involves a combination of mechanical and physiological factors, the Department has consented to assume responsibility for part of the cost, whilst the Department's Committee on Illumination has decided to carry out part of its work in close touch with the Board.

Close relations have continued with the National Institute of Industrial Psychology. In order to prevent misapprehension as to the relative functions of the two bodies, the Board think it desirable to point out that their own investigations are made with the sole object of acquiring knowledge on general lines, and not in order to benefit particular firms by studying problems specially applicable to them.

In the course of the investigation into Machine Design, all the Research Associations in the country were invited to assist the investigators with their advice. The Board desire to acknowledge the help received in this way from such Associations as had knowledge of machines deserving of investigation.

During a visit to the United States and Canada in the summer, the Secretary of the Board devoted some time to inquiries as to the nature and extent of work akin to that of the Board in progress in those countries. Valuable and instructive information was gained in this way, thanks to the frankness with which all those responsible for the work described their activities.

Mr. S. Wyatt has continued to act as Special Lecturer (part-time) in Psychology at the University of Manchester, and Mr. Farmer and Miss Smith have again participated in a course of

lectures at the London School of Economics as arranged by the National Institute of Industrial Psychology.

At the invitation of the Board of Trade Committee on Industry and Trade, evidence has been submitted to them by the Secretary of the Board.

5. Publications.

During the year now reviewed five reports have been published bringing the total number issued up to twenty-nine. Two of these deal with the effects of rest-pauses and of changes in activity respectively, both under practical and under laboratory conditions. A third consists of two studies on muscular work, namely a comparison between different methods of weight carrying and the influence of rest-pauses and changes of posture.

On account of the many variables involved and the usual impossibility of applying the method of pure experiment, the investigation of most industrial problems is necessarily founded largely on the application of statistical method, whether this consists in the simplest commonsense interpretation of numerical data or involves the employment of procedures of a highly technical character. The Board are specially indebted to Mr. G. Udny Yule, C.B.E., F.R.S., for having placed at their disposal for publication a lecture dealing with the function of statistical method in scientific investigation, and showing clearly the powers and limitations of statistical reasoning.

Finally, in order to bring into focus the points emerging from their previous work which seemed to deserve experimental application on the practical scale, the Board decided to issue a report giving a brief summary of the results of the investigations carried out by them in selected industries, comprising metal, textile, boot and shoe, pottery, glass, laundry, and repetition work generally.

In addition, three further reports (on monotony in work, performance tests, and rest-pauses respectively) are now in the press, bringing the total number of reports issued by the Board to thirty-two.

A full list of the reports appears on pp. 64-74.

Part II of the present Report consists of personal contributions on general topics from Mr. E. Farmer, Miss E. M. Newbold, Miss May Smith, Dr. H. M. Vernon, Mr. H. C. Weston, and Mr. S. Wyatt.

6. Conclusion.

With the issue of their Fifth Annual Report, the Board think the time appropriate for a short historical review of their past activities and for a survey of the present position in relation to industrial practice.

At the time of their appointment in July, 1918, inadequate attention had been paid in this country to the subject of industrial fatigue, and although striking results had been achieved by the Health of Munition Workers Committee, especially in regard to the uneconomic character of long hours of work, the remedy had by then been already applied and the hours shortened to reasonable limits. After the work of the Board had continued for five months, all of which was devoted to preliminary organisation and consideration of future policy, the war came to an end and they were confronted with the complete reorganisation of industrial practice involved in the change over to peace time conditions. Other unforeseen changes also occurred. The first substantial investigation, for example, was initiated into the iron and steel industry with a view to comparing the effects of the twelve- and eight-hour shift systems, but hardly had this been started, when by an agreement between the employers and the operatives the twelve-hour shift was abolished in February, 1919, and the eight-hour shift became universal throughout the country. This change precluded the Board from studying the question by means of current observation, and although they were able to gain much information on the subject, this was done by working backwards through records extending over the past.

From that time onwards there seemed some prospect that after the changes introduced with the end of the war, conditions as regards such important factors as hours of work would remain constant long enough to enable some comparison of the effects of other variables to be made. Trade did in fact remain prosperous and industrial conditions uniform for some time, and an excellent opportunity for investigation was provided, which, *inter alia*, enabled the Board to collect data in the cotton industry, showing that the unfavourable effects of high temperatures and humidity on the operatives brought about a loss of production. Then in the summer of 1920 industrial depression set in with unexampled suddenness, short time was introduced and conditions became altogether abnormal. This state has continued with short periods of alleviation up to the present, and has not only proved a serious obstacle to the progress of many of the Board's investigations, but has also made industries reluctant to embark on schemes of which the practical value has never been tested in this country.

The difficulties which the Board have had to face were indeed not unexpected, for they are inherent in all investigations into conditions subject to economic laws, but the extreme degree to which they have existed almost since the Board was constituted affords some explanation why progress in the strictly industrial side of their work has been smaller than the Board at one time hoped.

Turning now to the present, it may be of interest to refer to the Board's First Annual Report for the year ended 31st March,

1920, in which they indicate the lines on which their future work might usefully develop, and point out that it will probably involve three stages. To quote from the Report (p. 23) :—

> "In the first place there is the 'observational' stage—"
> "the collection of the actual data on which the final con-"
> "clusions are based; secondly, there is the 'critical' stage—"
> "the discovery of inefficiency and the causes underlying"
> "that inefficiency; and finally, there is the 'constructive'"
> "stage—the curative application of definite methods for the"
> "elimination or reduction of industrial fatigue and the increase"
> "of human efficiency."

The forecast then made by the Board has proved substantially accurate, and the second stage has already been reached in regard to certain matters in many of the industries investigated.

A brief but complete account of the conclusions reached, together with some indication of their definiteness, will be found in Report No. 27 (Results of Investigation in certain Industries), published during 1924. Two of these may be quoted here as illustrations.

In heavy manual work involving exposure to high temperatures (such as certain occupations in the tinplate and steel industries), output often undergoes a seasonal variation being greatest in winter, least in summer, and intermediate between the two in spring and autumn ; in extreme cases this variation may amount to as much as 20 or even 30 per cent. This effect, however, is much less marked in well-ventilated mills, and the comparative evenness of output in these suggests that most of the loss could be eliminated through the relief afforded by suitable ventilation. As a second example, the effects of rest-pauses in light repetition work may be mentioned. Investigations carried out by the Board consistently suggest that the judicious introduction of rest-pauses of 10 to 15 minutes into a spell of 4½ to 5 hours will eventually be followed by an increase in output of the order of 5 to 10 per cent., notwithstanding the shorter time actually worked.

Here, then, there are two clear indications (many others will be found in the report already referred to) of how the introduction of perfectly definite and comparatively simple changes will cause the human body and mind to respond in such a way as to bring about an increase in production. It is true that in the cases where this introduction is most easy, the differences recorded are often small, but it must be remembered, first that they are based on cautious estimates, and secondly that they generally represent the composite effect of changed conditions upon a large number of operatives, differing in their individual response to the change. It appears, therefore, justifiable to assume that a favourable effect estimated in this way would extend to the whole body of operatives engaged in a given occupation, and so would have a pronounced influence generally on the fitness of the workers and on production.

The Board, however, have used the word "indications" above advisedly, since, as they point out in their Fourth Annual Report, no absolute guarantee exists that the expected result will follow the change, and the final criterion is and always must be the results of application under actual conditions of work. This is the point at which the third or constructive stage, specified in the passage already quoted, is reached, and here industries themselves must clearly play the leading part.

In their last Annual Report the Board put forward certain suggestions as to the means by which this continuation might be secured. Briefly, these involved first the formation in each important industry of a small committee representative of employers and workmen to deal with questions affecting the human factor and to consult with bodies like the Board and the National Institute of Industrial Psychology; and secondly, the final testing of the conclusion concerned by experimental application confined to certain factories where the conditions seem to be specially suitable. The response made to these suggestions has up to the present been disappointing, and although they are now being considered by certain industries, no definite action has yet been decided upon.

The Board think that this apparent indifference may be due, first, to the fact that representatives of industry are, and have been in recent years, fully occupied with the discussion of questions calling for immediate settlement and have little time left for consideration of the future; secondly, to the financial stringency that has existed through the time of industrial depression; and, lastly, to failure to appreciate the real points at issue. They suggest, however, that just as in the past many difficulties would have been avoided by the adoption of some machinery to concentrate entirely on the future, so in this particular subject opportunities may be lost unless steps are now taken to look ahead. For there are unmistakable signs that in other countries the importance of the human factor in relation to production is gaining increased acknowledgment every year, and the speed with which this relationship can be developed in this country is contingent, not on the efforts of small bodies with limited resources, but on the initiation of a definite movement on the part of industries themselves.

They would therefore again emphasise two features of their work which have clearly emerged during the last six years. The past history of factory legislation shows that the successive industrial reforms introduced were justified by their supporters mainly on humanitarian grounds, it being generally assumed, in the absence of any evidence to the contrary, that the workers alone would benefit and (as admitted even by the reformers themselves) that the manufacturers might suffer. Probably the most important result of the Board's work has been the proof that the worker's well-being is not antagonistic to production, but that, on the contrary, maximum production is, in fact, contingent on maximum fitness on the part of the worker.

The Board are not unmindful that the comfort and well-being of their workers are matters of concern to many, and indeed to most, employers at the present day. It must, however, be remembered that the conditions underlying maximum fitness are not yet completely understood and that new knowledge on this subject is being constantly acquired. The indications as to how improvement in this respect can be secured, such as emerge from the investigations undertaken by the Board and the National Institute of Industrial Psychology, are then surely worthy of serious attention on the part of industry, if only for the reason that from the very method of their assessment, strong evidence exists that they will benefit the employer no less than the workman.

Secondly, the Board are doubtful whether the extent of the loss which arises from the present indifference to the physiological and psychological aspects of industry is fully realised. Part of this waste is disclosed in the official statement that the loss of time due to sickness, most of which is preventible, probably costs the country not less than ten times more than that which it loses owing to strikes and labour disputes.* Another attempt at its estimation in economic terms is made in a book recently published,† and whilst the conclusions reached are necessarily very tentative, they suffice to show that a needless waste of many millions of pounds annually could be prevented by the application of scientific methods to the functioning of the human element in industry. The book in question deals only with industry as a whole, and a much closer estimate could probably be carried out by a special survey of any given industry. Much of the work of the Board has consisted in attaching more or less definite numerical values to effects, which qualitatively are often already known to exist. With the aid of such quantitative standards, there is no inherent impossibility in obtaining a rough impression of the probable economic effect of their application in industry. The Board, therefore, are inclined to suggest that industries which are not at present disposed to regard these questions as an important factor in their national progress, should arrange for a short survey by a qualified person of their existing conditions on an economic basis, the conclusions reached being, of course, accompanied by the data supporting them. If this were done even on comparatively superficial lines, the results, in the conviction of the Board, would be such as to persuade the most conservative that here a field of enormous potentialities lies open to exploration in every class of industry.

The list of Committees given on p. 29 is a clear indication of the extent to which the Board, in carrying out their functions,

---

* Annual Report of the Chief Medical Officer of the Ministry of Health for 1923. (*H.M. Stationery Office.*)

† "The Economics of Fatigue and Unrest," by R. Sargant Florence (Allen and Unwin, 1924).

rely on the special knowledge and experience of others. The Board gratefully acknowledge the assistance they have always received, from both scientific and professional men, and from representatives of industry, often at the sacrifice of much convenience and time. But this free gift of knowledge for a national end surely cannot remain without its significance to industries generally, and it is difficult to believe that conclusions reached on such authoritative advice can long be ignored, or at least be regarded without trial as of little practical value.

The Board cannot conclude their Fifth Annual Report without a high tribute to the energy and ability of their staff of investigators, on whom they naturally most rely for the successful performance of their duties. The work of investigation has throughout proved difficult and exacting, and the Board know that the results set forth in their published reports have been obtained only by the exercise of much courage and in the face of many disappointments.

The Board desire also to record their thanks for the assistance given and the interest taken in their work by the many employers and workmen, with whom they have been in touch during their six years of existence and without whose active co-operation progress would have been impossible. Facilities for observation and experiment have been freely granted by employers, often at some temporary inconvenience, and many individual workmen have voluntarily devoted their time in assisting the Board to secure data of various kinds.

D. R. WILSON,
Secretary.

WILLIAM GRAHAM,
Chairman.

24th April, 1925.

APPENDIX.

COMMITTEES RELATED TO THE BOARD.

Scientific Committees.

Industrial Health Statistics.

Major Greenwood, F.R.C.P. (Medical Officer, Minister of Health), (*Chairman*).
John Brownlee, M.D., D.Sc. (Director of Statistics, Medical Research Council).
E. L. Collis, M.D., M.R.C.P. (Talbot Professor of Preventive Medicine, Cardiff).
A. Henry, F.I.A. (Deputy Government Actuary).
Leonard Hill, M.B., F.R.S. (Director of Applied Physiology, Medical Research Council).
L. Isserlis, M.A., D.Sc. (Statistician to the United Kingdom Chamber of Shipping).
A. S. MacNalty, M.D. (Medical Officer, Ministry of Health).
T. H. C. Stevenson, C.B.E., M.D. (General Register Office).
G. Udny Yule, C.B.E., M.A., F.R.S. (University Lecturer in Statistics, Cambridge).
E. L. Faning (*Secretary*).

Physiology of Muscular Work.

E. H. Starling, C.M.G., M.D., F.R.S. (Foulerton Research Professor, Royal Society), (*Chairman*).
E. P. Cathcart, C.B.E., D.Sc., M.D., F.R.S. (Professor of Physiology, University of Glasgow).
A. V. Hill, O.B.E., Sc.D., F.R.S. (Professor of Physiology, University of Manchester).
M. S. Pembrey, M.D., F.R.S. (Professor of Physiology, Guy's Hospital).

Industrial Psychology.

Henry Head, M.D., F.R.S. (Member of the Medical Research Council), (*Chairman*).
F. C. Bartlett, M.A. (Director of the Psychological Laboratory, Cambridge).
Cyril Burt, D.Sc. (Psychologist to the London County Council).
C. S. Myers, C.B.E., Sc.D., M.D., F.R.S. (Director of the National Institute of Industrial Psychology).
T. H. Pear, M.A. (Professor of Psychology, University of Manchester).
Sir Charles Sherrington, O.M., G.B.E., Sc.D., Pres. R.S. (Professor of Physiology, University of Oxford).

Special Committees.

Post Office Work.

C. J. Bond, C.M.G., F.R.C.S. (Member of the Board), (*Chairman*); Henry Head, M.D., F.R.S., and C. Burt, M.A. (Committee on Industrial Psychology); M. Greenwood, F.R.C.P. (Committee on Industrial Health Statistics); John Lee, C.B.E. (Controller, Central Telegraph Office); M. S. Pembrey, M.D., F.R.S. (Committee on Physiology of Muscular Work); H. V. Prynne, C.B.E., D.S.O. (Chief Medical Officer to the Post Office); Mona Wilson (Member of the Board).

Accident Causation.

R. R. Bannatyne, C.B., (Member of the Board), (*Chairman*); Henry Head, M.D., F.R.S., and F. C. Bartlett, M.A. (Committee on Industrial Psychology); G. Udny Yule, C.B.E., F.R.S. (Committee on Industrial Health Statistics).

Optimum Length of Spell.

Rt. Hon. W. Graham, M.P., (Chairman of the Board) (*Chairman*); Sir Gerald Bellhouse, C.B.E. (H.M. Chief Inspector of Factories); A. V. Hill, Sc.D., F.R.S. (Committee on Physiology of Muscular Work); C. S. Myers, C.B.E., M.D., F.R.S., and T. H. Pear, M.A. (Committee on Industrial Psychology); G. Udny Yule, F.R.S. (Committee on Industrial Health Statistics).

Physiology of Ventilation.

Leonard Hill, F.R.S. (*Chairman*); J. C. Bridge, F.R.C.S.Ed. (H.M. Medical Inspector of Factories); E. L. Collis, M.D. (Miners' Health Advisory Committee); C. A. Lovatt Evans, D.Sc. (Professor of Physiology, St. Bartholomew's Hospital); M. Greenwood, M.R.C.P., and L. Isserlis, D.Sc. (Committee of Industrial Health Statistics); G. Stevenson Taylor (H.M. Engineering Inspector of Factories).

Design of Machinery.

E. H. Starling, C.M.G., F.R.S. (Member of the Board) (*Chairman*); E. P. Cathcart, C.B.E., D.Sc., M.D., F.R.S. (Professor of Physiology, University of Glasgow); Sir John Dewrance, K.B.E., Sir Joseph Petavel, K.B.E., F.R.S., and Engineer-Captain I. E. F. Roberts, R.N. (nominated by the Department of Scientific and Industrial Research); D. R. Wilson, (Secretary to the Board); G. H. Miles, D.Sc. (Assistant Director, National Institute of Industrial Psychology) (*Secretary*).

Industries Specially Affecting Women.

Winifred Cullis, O.B.E., D.Sc. (Professor of Physiology, University of London) (*Chairman*); Mona Wilson; Hilda Martindale, O.B.E. (H.M. Superintending Inspector of Factories); Isabel H. Sloan (Ministry of Labour).

Sickness in Cotton Weaving.

M. Greenwood, F.R.C.P. (*Chairman*); E. L. Collis, M.D., and A. Henry, F.I.A. (Committee on Industrial Health Statistics); John Jackson, O.B.E.; F. Scarisbrick; Cephas Speak, J.P.; and T. P. Threlkeld (Departmental Committee on Humidity in Weaving Sheds); D. R. Wilson (*Secretary*).

PART II.—PERSONAL CONTRIBUTIONS FROM INVESTIGATORS.

A.—LEARNING CURVES IN INDUSTRY.

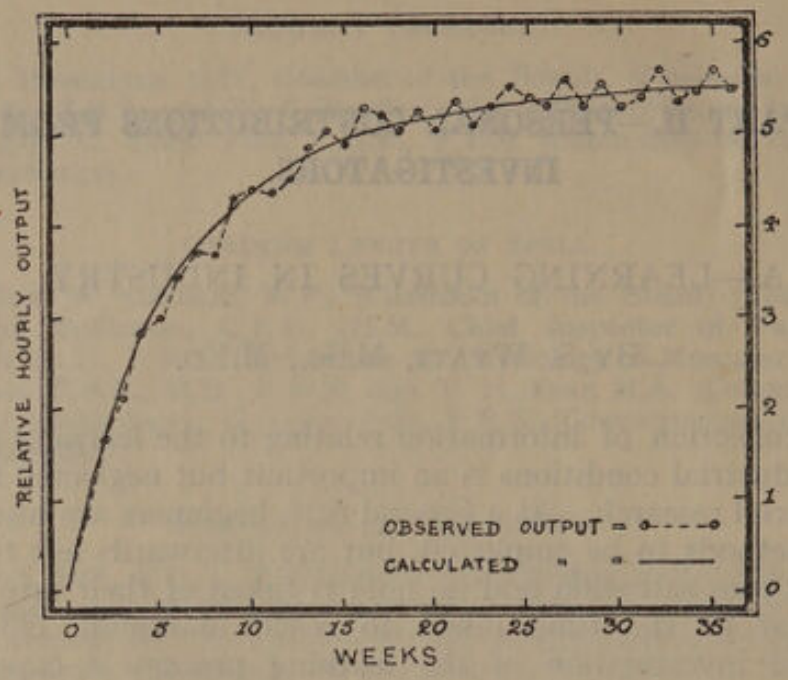
By S. Wyatt, M.Sc., M.Ed.

The collection of information relating to the learning process under industrial conditions is an important but neglected feature of industrial research. As a general rule, beginners are instructed in the methods to be employed, but are afterwards left to work out their own salvation and no note is taken of their rate of improvement or the time taken to reach maximum efficiency. A careful investigation of the learning process is capable of disclosing a mass of useful information of considerable economic and psychological value. It would show, for instance, the general features of the learning process and the nature and extent of individual deviations from the average type of curve. The relation between initial and ultimate efficiency could also be obtained, and the learning curves for different types of work would give some indication of the amount of skill involved in different industrial tasks. A knowledge of the duration of the learning period is an economic necessity, and yet in most industrial establishments it is conspicuous by its absence. When it is realised that the collection of information on the learning process is only a matter of utilising existing data, and could be done by welfare supervisers or individuals employed in a somewhat similar capacity, it is regrettable that such an important mine of information is allowed to remain unworked.

In the following remarks some attempt will be made to indicate the importance of the learning process in industry, and to suggest the method of procedure necessary for the collection of information in this connection.

General Features of the Learning Curve.

It will be generally agreed that most industrial operations require a certain skill for their efficient performance, although the general tendency of industrial development is towards the simplification of processes and a consequent reduction in the amount of skill involved. Even in the simplest operations, however, a considerable time usually elapses before the beginner reaches the stage of maximum efficiency, and this phase of industrial work is usually characterised by certain well-marked tendencies, which may be illustrated by reference to the following curve.



The above curve refers to twelve beginners employed in the process of machining handkerchiefs, and represents the average hourly wage earned by these operatives in successive weeks. The continuous line represents the ' smooth ' curve corresponding to the observed values.

The curve is probably fairly typical of the results obtained in connection with the learning process under similar industrial conditions. The rate of improvement is rapid at first, but progressively decreases as work proceeds.

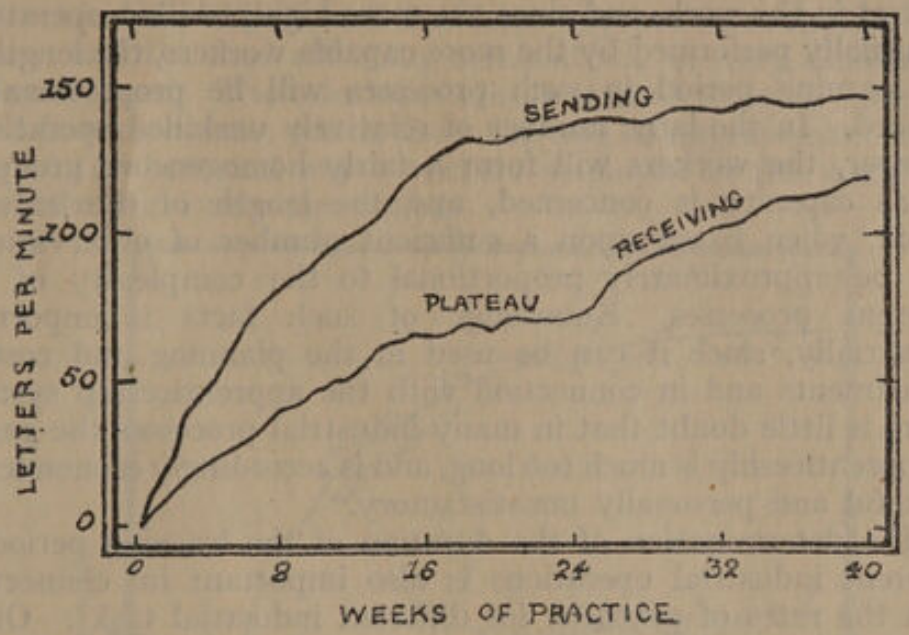
The increase in efficiency in the learning period is due to a gradual elimination of clumsy and unnecessary movements, together with improved mental and muscular co-ordination. At the outset a considerable amount of attention is usually required but, as work proceeds, this becomes increasingly unnecessary, and ultimately the operation may become practically automatic.

In the process under observation 82 per cent. of the efficiency observed in the final week (the 36th) is attained in the 12th week, and this is increased to 95 per cent. in the 24th week. Even at the end of the 36th week, however, the average efficiency is still slowly increasing, thus indicating that the operatives have not yet reached the stage of maximum efficiency.

There is some evidence to show that, in certain operations, the improvement during the learning process is not continuous, but is interrupted by a period in which the efficiency (as shown by the learning curve) remains approximately stationary. This feature of the curve is known as a ' plateau ' and was first observed by Bryan and Harter,* in their investigations on telegraphic learning. It was found to occur only in the receiving, and not in the sending operations.

---

* Psychological Review. Vol. IV.



It has been suggested that the difference in the form of the two curves is due to the fact that receiving involves higher and more complex mental processes than sending. "In receiving signals, one first learns the groups of sounds, corresponding to each letter, and then a considerable time must elapse before one can organise into larger wholes the perception of these elementary groups, thus apprehending words or phrases. The plateau, then, may mark a stage of internal mental organisation of a rather high order."†

It is evident, therefore, that the actual form of the learning curve depends upon the type (or complexity) of the process to be learned, and this again may be shewn to be in part dependent upon the temperament of the individual learner, and the method which he adopts. It is probable that the collection of information on the learning process in industry will reveal definite types of curves corresponding to particular conditions.

Relation to Type of Work.

Given a representative group of workers, the duration of the learning period will depend upon the complexity and difficulty of the industrial task. In a simple operation such as packing tablets of soap in cartons it may last only a few weeks, but in a process such as glass-blowing it may take the beginner months or even years to become fully experienced. In general, the length of the learning period will be proportional to the amount of skill required in the efficient performance of an industrial operation, and the determination of this period would accordingly enable industrial operations to be graded according to the complexity of the task, and particularly the degree to which mental and muscular operations must be co-ordinated. The time taken to become efficient is, of course, also dependent upon the ability of the workers and their

† T. H. Pear: "Skill in Work and play." London. 1924. Page 51.

interest in the work, and since the more highly skilled operations are usually performed by the more capable workers, the length of the learning period in such processes will be proportionately reduced. In the large number of relatively unskilled operations, however, the workers will form a fairly homogeneous group as far as capacity is concerned, and the length of the learning period, when based upon a sufficient number of observations, will be approximately proportional to the complexity of the different processes. Knowledge of such facts is important industrially, since it can be used in the planning and costing departments and in connection with the apprenticeship system. There is little doubt that in many industrial processes the period of apprenticeship is much too long, and is accordingly economically wasteful and personally unsatisfactory.

The determination of the duration of the learning period in different industrial operations is also important in connection with the rates of payment for different industrial tasks. Other things being equal, the final rate of payment should bear some relation to the duration of the learning period, which is an indication of the degree of complexity involved. The more highly paid process will be obviously the one which involves the greater complexity and thereby requires the longer to learn. Systems of payment based upon this principle would undoubtedly remove many of the inequalities which exist in the rates of payment in different processes and industries.

Learning curves are also useful as a means of determining the extent of the productive loss involved in labour turnover. Each time a worker leaves, and is replaced by another, a partial or complete re-learning of the industrial task is necessary, with its accompanying loss in productive efficiency. When the labour turnover is high, this loss is very considerable, and increases with the complexity of the industrial process. It has been shown that labour turnover is particularly high in the early months of service.* This usually means that just as the beginner is approaching or has reached the stage of maximum efficiency, and is consequently of maximum value to herself and the firm, she tends to leave and the wasteful learning process must be repeated with another worker.

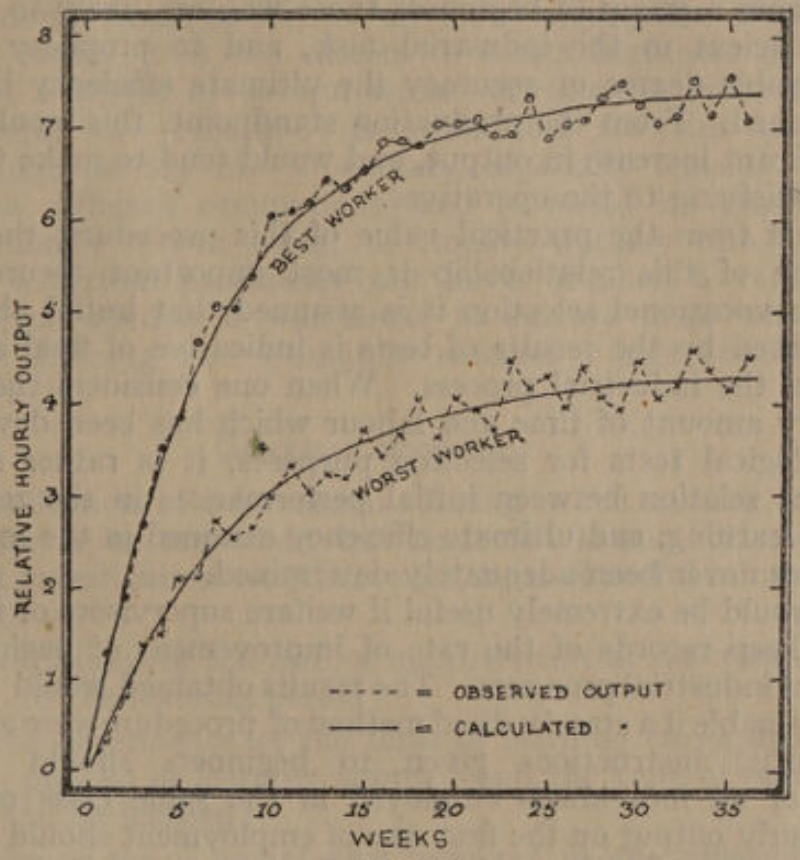
Learning curves may also be of value in ascertaining the effect of certain modifications in the conditions of work. The effect of modified methods of instruction, for instance, will be shown by the type of learning curve obtained before and after the change, and a numerical estimation of the effect is thereby rendered possible.

Individual Differences.

A characteristic feature of the learning process is the differences in the behaviour of individuals employed on the same kind of work. Although the conditions of work may be the same for

* *Cf.* Report No. 13 of the Industrial Fatigue Research Board, p. 16.

all workers, it will be found that some improve more rapidly than others, and the final efficiency attained will be very different in different cases. These features are illustrated to some extent in the following curves, which show the rate of improvement in the case of the best and worst workers employed in the machining operation previously mentioned.



Thus, at the end of the 36th week, the efficiency of the best worker is approximately 75 per cent. better than that of the worst. Throughout the learning period, also, her rate of improvement is much the greater, and such a difference is fairly typical of the results obtained in all forms of dexterous handwork. Since, in each homogeneous group of workers, the methods of instruction and conditions of work are presumably the same for all workers, the differences in the rate of improvement and ultimate efficiency must be due almost entirely to innate differences in the capacities required for the efficient performance of that task. In any group of applicants selected at random, it will be found that if the average efficiency of the group is 70 per cent. a few individuals may attain an efficiency of 95 to 100 per cent. while a similar number will be incapable of exceeding 40 to 45 per cent. The same group of operatives employed on different work, although giving a similar numerical range and distribution of efficiency, would probably reveal a different arrangement of individual efficiencies within the group. Thus some of those who showed efficiencies of 40 to 50 per cent. in the former task, might give efficiencies of 60 to 70 per cent. in the latter, and vice versa. If this is so, and existing evidence supports this view, it should

be possible to separate the applicants according to their degree of suitability for any industrial task by means of suitable tests.

In this connection the relation between initial and ultimate efficiency is of considerable practical importance. If it were established that initial efficiency is highly correlated with the rate of improvement and final efficiency, it would be possible to select from a group of beginners those who are likely to become most efficient in the industrial task, and to prophesy with a considerable degree of accuracy the ultimate efficiency likely to be attained. From the production standpoint, this would mean a significant increase in output, and would tend to make the task more satisfying to the operatives.

Apart from the practical value of this procedure, the determination of this relationship is most important theoretically, since in vocational selection it is assumed that initial ability as represented by the results of tests is indicative of final achievement in the industrial process. When one considers the extraordinary amount of time and labour which has been devoted to psychological tests for selection purposes, it is rather singular that the relation between initial performances in the tests, the rate of learning, and ultimate efficiency attained in the industrial task, has never been adequately determined.

It would be extremely useful if welfare supervisors or foremen would keep records of the rate of improvement of beginners in different industrial processes. The results obtained would be even more valuable if a standardised method of procedure were adopted. The initial instructions given to beginners should be the same for all individuals employed in the same class of work. The hourly output on the first day of employment should then be ascertained, and afterwards the daily output until the worker becomes fully experienced. By this means it would be possible to determine the correlation between initial ability, as represented by the output in the first hour of work, and final achievement, in the form of the ultimate efficiency attained. If a close correlation exists, then the behaviour in the first hour of employment would provide an accurate index of individual suitability for the particular industrial process, and from a number of beginners, those who are likely to succeed could be selected. If the output in the first hour of work failed to give a sufficiently high correlation with ultimate efficiency, better results might be obtained by using the output in the first spell or day of employment, but the most suitable period of activity for this purpose could only be determined by a statistical treatment of the results obtained. In any case, a thorough investigation of this aspect of the learning process is urgently needed, and should be undertaken without delay in processes where suitable conditions exist.

Lastly, as has been suggested by Farmer,[1] if reliable output records could be collected over a number of years it would be

[1] In a memorandum submitted to the Industrial Fatigue Research Board.

possible to determine the effect of improvement at various ages and with different sexes. Such results would disclose the most suitable age at which workers should take up different occupations. According to Farmer, there is great reluctance in some industries to accept adult beginners, although many industrialists confess to some doubt on the matter, and if light could be thrown on this question it would be of great service to employment managers. In some trades, it is the custom to assign beginners to "odd jobs" for a period of several weeks or months, consequently older people are regarded as unsuitable for this purpose. The average factory life of workers, especially females, varies greatly in different occupations, and it would be possible to decide whether it was better to employ workers who quickly attained a certain proficiency but never reached a very high standard, or whether it was better to employ those who were slower at learning but ultimately reached a high standard of efficiency.

General Summary.

The collection of information relating to the learning process in industry is an important but neglected feature of research. A careful investigation would reveal a mass of useful information relating to :—

(*a*) variations in the rate of improvement at different stages in the learning period ;

(*b*) the dependence of the form of learning curve upon the process of learning adopted and the type of operation to be learned ;

(*c*) the degree of complexity involved in the efficient performance of different industrial operations, and the grading of such operations according to the complexity. Information of this kind is important in connection with the rates of payment in different industrial processes ;

(*d*) the extent of the productive loss involved in labour turnover ;

(*e*) the nature and extent of individual differences in the rate of learning the same industrial task ;

(*f*) the relation between initial and ultimate efficiency and its application to problems connected with the selection of workers ;

(*g*) the determination of the most suitable age for workers to enter different occupations.

The collection of data relating to the learning process could be carried out by welfare supervisors or persons employed in a somewhat similar capacity.

B.—A NOTE ON SOME EXCEPTIONAL WORK CURVES RELATED TO MENTAL STATES.

By May Smith, M.A.

In many of the investigations on which the Board have been engaged, the effect on the worker's body and mind of conditions of work has been measured in terms of variations in output. The researches of the last few years have disclosed certain general tendencies in the daily work curve, when the records of many different workers over long periods are combined.

There seems to be a general increase in efficiency during the first hour or two, a relative stability for some time, and then a gradual decrease during the last hour. When, however, individual records are obtained, although many conform to the general type, yet there are interesting exceptions which show consistent deviations from this. A few illustrations may be given :—

(*a*) There are workers whose output records vary round about two means, one very good, one very poor. In the case of one worker, the output records over several months varied round about 1,600 units of work at one time and about 1,800 units at another, the intervening value of 1,700 units being never attained. Where the work is of an artistic nature and the worker is considered unusually good, this type of variation is usually accepted as inevitable; but it is also found in work of a common-place character in people of mediocre ability. In a few cases it has been possible to learn something of the mental make-up of the worker. One woman with this type of work curve has always been liable to sudden fits of depression; she has now, and has always had, an undue fear of authority, showing itself in an exaggerated anxiety to please, alternating with an almost truculent resistance; she is over-scrupulous, but with a manner at times suggestive of sullen indifference. She has physical symptoms which it is not idle to assume were intimately bound up with her mental state. As yet she has not had a serious nervous breakdown, but her mental state gives no assurance of future stability; her sick leave is considerable, and she is described as "nervy." In another case a man occupying a responsible position is described by a colleague thus: "You never know whether what he does will be very good or very bad; he never manages to find a medium." His mental state is very similar to that of the girl just described. Neither of them seems to have control over the personal conditions determining the type of work

(*b*) Another type of work curve, belonging also to so-called "nervy" people, has one mean, but the particular records show an unusual range of variation about that mean. It differs from the previous type in its possibility of being not only very good or very poor, but also ordinary. In a few cases where a mental diagnosis was possible, there have been revealed difficulties and stresses of an emotional character which were probably being exhibited as symptoms in the work.

(*c*) Another variation shows when graphed a curve almost like an inverted normal work curve. The work starts badly but does not improve till towards the end, just when other people are beginning to decrease in efficiency; the afternoon is better than the morning, the end of a period better than the beginning. Any one may occasionally work in this way, but where it is continued as a "regular irregularity," it will be found associated with other symptoms, such as much sick leave, headaches, irritability, a feeling of being "on edge."

The most reasonable explanation of these exceptional work curves is to be found in the mental make-up of the individual and in his attitude towards his work, and it appears that a careful study of these might eventually throw light on certain problems which are prominent in industry to-day.

In certain occupations for instance, particularly those in which the worker plays a more important part than the machine, there are frequent complaints and requests for help both from employers and workers for conditions described colloquially as "having nerves" if the emphasis is placed on the person, or as "nervy jobs," if the emphasis is on the work, or if the ægis of the medical profession is desired, as "neurasthenia." It is not uncommon to be told by a girl that she has nothing much wrong except that she suffers from nerves. Some employers, however, are seriously perturbed about the loss of efficiency involved in the form not only of sick leave, but of inadequate work and of irritability affecting fellow-workers as well. People of robust type scornfully dismiss the problem with the magic word "hysteria," but a label is neither soothing nor practical when the alternatives of dismissing the worker or of enduring the "nerves" are confronted.

The precise connection between the form of work curve and the mental state of the individual is still to be established, but there are unquestionably certain types of workers whose subjective characteristics would most probably be reflected objectively in special forms of curve.

There is the person best described as over-anxious; he is sensitive to the criticisms of others and ever expectant of them, imaginative, fearful lest he should make mistakes, alive to his responsibilities; he worries about what he cannot alter and is unable to dismiss from his mind the work he has done. If a dispenser,

such a person worries over his prescriptions, fears lest he has put poison in by mistake ; if a secretary, he is worried in case he has incorrectly addressed an envelope, put London for example instead of Leamington, omitted to put Esq. after a name, left out decimal points or noughts in statistics, and sees the mistake he has not made as a clear visual image ; if a telegraphist, he fears lest he should not be able to send a particular letter, or that a telegram already dispatched is wrong ; if a shorthand-writer, he has anxiety about interpreting his notes.

Another form of this anxiety appears at first sight to be much more objective and therefore real, in so far as the focus of interest, or rather of anxiety, is outside the person himself. Such a person does not worry in terms of "I may have made a mistake," but in terms of the work or of its conditions. Thus, a typist will have an undue amount of machine trouble, something will be too loose or too tight, or her manuscript will be difficult to read ; a telegraphist will find the key unsuitable ; a factory worker will question the correctness of the work coming from another department, or the state of the machine.

It is not suggested that these difficulties are not sometimes quite real, for they undoubtedly are so ; but when they regularly occur to one person and not to another, the chances are that their apparently objective character is illusory. A person of this type must not be confused with the constitutional grouser, whom at first sight he may resemble. The complaints made are not really criticisms of the objective conditions, but of himself.

Another variant suffers from an inability to accept any piece of work as finished ; mentally he is vaguely striving after some impossible standard, trying to please an unknown and implacable authority. That the authority is within himself and not an objective one, is shown by his incapacity to be satisfied even with the expressed approval of his actual authorities. He refines and refines on his work if allowed, and can never realise that there are occasions when the quantity of the work done is of more importance than the quality. An attempt to obtain quantity at the expense of quality will be met by irritability and general dissatisfaction, in some cases to the extent of ceasing work. Small things disturb him and he is unduly upset by the unimportant mischances which others pass by unnoticed. Left to work under his own self-imposed conditions, such a person does as a rule good work but with a low output. To obtain the actual output in terms of the work done and not only of the finished product, one would need to know all the rejected pieces of work. A typist of this kind would tear her page of typing from her machine if it had a small blemish and begin again, even though it could have been altered sufficiently for the purpose required.

These are a few of the so-called " nervy " people ; the descriptions are not offered as complete, but as covering some not

uncommon types. Only those symptoms are given which are reflected in the work or are recognisable by untrained observers.

It should be noted that the types described are neither malingerers nor hysterics, both of which are present in most fairly large groups; nor are they people leading an abnormal life of excitement which is influencing the work; they are ordinary people carrying on their work to the best of their power, but are closer to the psycho-neurotic than to the normal. They are usually enduring a considerable amount of mental suffering, and in the long run their work must be seriously affected. The energy which should be available for a given piece of work is divided between the work and the worry; hence arise the bodily symptoms of lassitude, headache, digestive troubles, yielding to no ordinary treatment.

Practically everybody is liable to be somewhat apprehensive when undertaking new work, but these people have been sufficiently long at their job to know it well and to know that they know it well. Their anxieties are not reasonable and are in marked contrast to reasonable fears. It is reasonable for a man getting on in years to be anxious about the insecurity of his tenure, but if he gets security then the anxiety should fade away as he realizes the changed condition. An unreasonable anxiety is not dissipated by change of objective conditions, but will attach itself to something else apparently also objective. There is a fixity of reaction with these types in marked contrast with the flexibility of the more normal.

People in authority could do much to alleviate the lot of some of these; sometimes even talking over the mental state to someone who understands is of great assistance. The time may come when it will be as usual to treat these mental symptoms as the physical now are; that end is not yet in sight. Meantime a more careful study of occupations is necessary, a study which shall take into account not only the requirements of the task seen in isolation or of the machine, but also the effect of the total conditions on minds of different types. For example, if one asks what are the chief qualities required for a job, a common answer is speed with accuracy, and it is not difficult to devise tests which shall test it. But one needs really to know much more, e.g., is the speed with accuracy to be maintained at equal pressure all day? Are there periods of rush alternating with slacker periods? Is the speed with accuracy to be expressed in terms of concrete things or of figures or words? It does not follow that a worker who is quick and accurate when dealing with concrete objects, will be equally so when dealing with the symbols of those objects.

Again, many occupations necessitate a capacity for working with others; one person may work happily when alone, but may suffer unreasonable anxiety when working with others. To be able to work under certain specified conditions is as essential for the allocation of a job as to be able to do the job itself. A shorthand-typist may be an excellent worker and yet

be almost incompetent, if she becomes either over-worried in the presence of an irritable employer or terrified lest she should fail to interpret her notes. Such a shorthand-typist must either be able to develop some understanding of the irritability of her employer, or become indifferent to it, or break down with "nerves." The conditions of the work may require a capacity for taking down notes from an irritable person, quite as much as a general capacity for taking down notes.

Contrast two dispensers of similar physique, health, training and experience. A is of the anxious type described above. B is not, but takes each case as it comes along, does it to the best of her ability, and having done it, leaves it as finished; she can study it as long as it is unfinished, but then she ceases to think about it. Such a person may fall ill sometimes, but she is unlikely to have a nervous breakdown. A may be all right for a time, but should any extra pressure be exerted, or her general health be not quite so good, or another dispenser make a mistake and thereby acquire unpleasant publicity, then it does not require much insight to know that she will have a nervous breakdown. Whatever may be the precipitating cause, the real cause is to be found in her mental make-up. And yet dispensing is quite often recommended to girls on grounds dealing only with intellectual equipment; actually it is an occupation which gives every opportunity for the expression in work of anxiety conditions.

The incidence of "nerves" seems to be greater among the clerical and allied occupations than in the factories, but neither the permanence nor the instability of the conditions of employment would appear to be the determining factor; the complaint of many nervous breakdowns in some form is found both with the relatively insecure tenure of the commercial world and with the permanent conditions of pensionable Departments.

C.—THE METHOD OF GROUPING BY DIFFERENTIAL TESTS IN RELATION TO ACCIDENT PRONENESS.

By E. Farmer, M.A.

The Board's last Annual Report contained a short account of certain aspects of the "test method." The present article deals with that method as applied to accident causation concerning which the Board has been engaged in carrying out research for some time past, and is likely to be for some time to come. The problem may be simply stated by asking why it is that in any group of workers exposed to the same risk for the same length of time some sustain more accidents than others. Sometimes the question is answered quite simply by saying that some people are more careless than others. Such an answer may, or may not, be true, but in any case it does not help us to understand the problem in the least. Very often the only reason for thinking a person is careless is because he sustains an undue proportion of accidents, but to argue thus is to argue in a circle. Even if we do not commit such a gross error we must still go on to ask what carelessness is and how it can be detected before it manifests itself in causing an accident.

We already know from work the Board has published, which has been corroborated by further research which has not at present been published, that people differ in their degree of proneness to accidents. This does not mean that there is a group who have accidents and a group who do not, but that people exposed to equal risk will tend to sustain accidents according to their degree of proneness. The task, therefore, that is presented to the psychologist is to devise tests which will correlate with proneness to sustain accidents. He is not merely required to test for some specific mental or physical factor, but he has to discover the particular mental and physical factors which in combination differentiate people according to their liability to sustain accidents. His methods must be analytical, and he must examine as far as he can each of the possible mental and physical factors which may enter into the cause.

A series of tests will have to be devised which are presumed to test some special characteristic such as neuro-muscular ability, which it seems probable has a bearing on accident proneness. The results of these tests must then be correlated with the number of accidents each individual in the group has sustained within a given period of exposure. The greatest care must, of course, be exercised in order to make sure that the accident records have been kept in such a way as to make them reliable indicators of accident proneness, and it is also most important that each individual should have been exposed to the same amount of risk during the observational period. The best way to insure this is to confine oneself in the early stages of the investigation to

individual repetition processes in which each worker is performing exactly the same operation as every other worker in the group, and where accidents can only be sustained as a result of the individual worker's movements and cannot be caused by another worker, or by defective machinery.

If there are significant correlations between any of the tests and the number of accidents sustained by members of the group, the next step in the research will be to endeavour to improve those tests which correlate most highly with accident proneness and also to examine the inter-correlations of the various tests. If it is found that certain tests correlate highly among themselves it may sometimes be possible to eliminate some of the tests and still get equally good final results. From a practical point of view this is always desirable because it makes for simplification, but great caution must be exercised before the elimination of any test is resorted to, and it should never be done until the results of a long series of experiments consistently point in the same direction.

The next step is to find another test which correlates significantly with accident proneness but which does not correlate with the tests already used. This will be done by examining some other individual characteristic differing qualitatively from the first, and the process must be continued until we reach a final correlation with accident proneness which is sufficiently high to be of practical value. This, of course, may never be possible on account of the limitations which our own ignorance of psychology places upon us, but the object of the research is to find out how near we can approach to complete knowledge of the factors governing accident causation.

It has been said above that in the preliminary investigations we should confine our attention to groups of workers who are employed on individual repetition work entirely under their own control in order to make sure that exposure to risk is equal. Having by this means established the validity of our tests, we must, in order to be of practical service, pass on to other occupations where we cannot be certain that the exposure to risk is absolutely equal. For instance, in a group of engineers we shall find that some sustain more accidents than others. In skilled trades of this kind it is impossible to say exactly how a worker was employed each hour of the observational period, so that the assumption we are bound to make is that those workers who sustained an abnormally large number of accidents were probably exposed to greater risks than the others, by using more dangerous machinery or tools. If, however, we test such a group and find that our tests yield significant correlations with the number of accidents sustained, in spite of the known inequality of exposure to risks, then in order to maintain that the number of accidents sustained is entirely due to the inequality in exposure, we have to make the further assumption that those who were likely to fail in the tests were on the whole employed on the more dangerous operations. The probability of such a chance coincidence being

true is so infinitesimal as to make it almost an impossibility when significant correlations between the tests and numbers of accidents are found consistently over a long series of experiments in which exposure to risk cannot be accurately measured. This is, of course, provided that the results of the tests have played no part in the allocation of the work, which in the Board's researches can never be the case, for the results of the tests are correlated with the accident incidence for the previous year.

We can still entertain doubt as to which is the more potent factor, inequality of exposure, or personal idiosyncrasies, but if the tests prove significant we cannot rule out the personal factor. It would be futile to argue on one side or the other, for the matter can easily be put to the test by excluding new workers who fail in the tests from one particular department, and seeing how the accident rate of that department is affected. There will still be unequal distribution in the accident incidence due to unequal exposure, but if the total accident rate over a series of years is lessened, then the amount by which it is lessened is a measure of the degree in which the personal factor as indicated by the tests is operative.

In estimating the nature of the test method we must always bear in mind that although it deals with individuals it does not deal with them as such but only as members of a group. We may say of a group of individuals who have passed any test which correlates significantly and highly with accident proneness, that the group as a whole will be less likely to sustain accidents than a group selected without reference to the tests. We cannot, however, say that any particular individual in the group will be less likely to sustain accidents than a particular individual in a chance group.

Sufficient has been said of the methods and difficulties of the Board's work in this particular sphere to make it plain that progress must be slow. There is already evidence from the experiments that have been carried out to show that it is possible to indicate beforehand, by means of properly devised tests, those who are particularly susceptible to accidents; but before practical use can be made of the tests further work must be carried out in order to test their reliability over a wider sphere, and also in order to establish norms of performances, and it is for this reason that the Board is continuing the research so as to avoid publishing results of an immature nature.

D.—INDUSTRIAL SICKNESS STATISTICS

By Ethel M. Newbold, B.A.

It is not unnatural that an investigator under a Board whose terms of reference cover schemes of research "having regard to the preservation of health among the workers" should sometimes be asked for information as to what sort of standards there are for appraising the amount of sickness observed in any particular case. Hence it may be of interest to some—even at the risk of boring others by going over familiar ground—to consider again a few of the reasons why we have so little quantitative knowledge of the general incidence of illness, and some of the fallacies and pitfalls that lie in our path when we deal with industrial sickness statistics from the point of view of the effect upon health of different occupations.

I am not for the time being thinking of the more specialised industrial diseases connected with certain processes or materials. These, though each presents its own problems, yet by reason of their specialisation, offer a comparatively easier field for their detection and for the study of preventive measures. The large mass of sickness of the industrial worker is made up of ailments which he has in common with the general population, and the variations in the incidence of this sickness, both as to amount and kind, apart from their general importance to the whole community, are of special interest to those connected with any particular industry, who want to know how their industry stands in this respect with regard to other industries, and in particular to individual firms, many of whom now keep records in more or less detail, of absence from sickness among their workers, and want to know in what respects their experience is above or below the average of the industry to which they belong.

The first thing wanted is, of course, a standard of comparison, and no such general standard exists—we do not know with any accuracy the average amount of illness, either from all causes or from particular diseases (except to some extent those compulsorily notifiable) that is to be expected in different sections of the population. Many schemes have been proposed and practical attempts made—some for general and some for particular purposes—to compile sickness statistics of a more or less comprehensive character. The history of these analyses is scattered in various periodicals and official reports, but short outlines of the more important are given in the papers cited below by Newsholme

(1896)¶ and (1912),* Rusher (1922),† and Dudfield (1923).‡ The sources suggested or already used comprise :—Poor Law returns, hospital or other institutional records, Police, Army and Navy registers, private or official enquiries in a definite limited field, and lastly—but by far the most important numerically—the increasing volume of figures possessed by Insurance and Friendly Societies covering formerly all their voluntary members, and more recently all who come under the National Insurance Act.

How far is it possible to get from such sources general information of a kind to throw light on the causation of ill-health by industrial occupation ? The two first questions to be answered are :—What do such figures measure, and among what population do they measure it ? Take the second question first and consider the records of insurance benefits. A single society or branch is not necessarily confined to a single trade, and the usual practice appears to be for a member to be registered under the occupation followed at the time of first entering the society. Change of trade may take place without any note of it being made on the member's card. Among the older men, and in the more skilled trades and in societies confined to one trade union, such changes may be negligible, but, especially directly after the war, this was found to be a source of error and was one of the reasons why some of the investigations into trade sickness projected by the Industrial Fatigue Research Board at that time were not pursued further. Suppose, however, that this difficulty was overcome and we had got the entries confined to a single trade, a much more elusive difficulty confronts us—one which is familiar also as obscuring attempts to trace causal relationships from occupational mortality statistics—viz., that many occupations are obviously selective as regards health and general physical fitness in the type of worker they attract or repel, or, as Dr. Ogle put it, " The several industries do not start on equal terms as regards the vitality of those who follow them."§ On this point the warnings given by the Registrar-General in his introduction to the latest report on Occupational Mortality‖ are equally applicable to occupational sickness :—" For example, it will appear from the tables that engine drivers and motor car drivers are subject to abnormally low death-rates. But before it can be inferred that engine driving and motor car driving are subject to a relatively

¶ A National System of Notification and Registration of Sickness by Arthur Newsholme, Journal of Royal Statistical Society, Vol. LIX, March 1896.

* Report to the Local Government Board (new series No. 64) 1912. Statistics of the Incidence of Notifiable Infectious Diseases in 1911, Historical Statement, pp. 3–6.

† The Statistics of Industrial Morbidity in Great Britain. Journal of Royal Statistical Society, Vol. LXXXV, 1922.

‡ " The Registration of Disease." Opening by Dr. R. Dudfield of a discussion. Journal of Royal Statistical Society, Vol. LXXXVI II, March 1923.

§ Suppt. to 45th Ann. Rept. of the R.G., 1885, p. xxiii.

‖ Mortality of Men in Certain Occupations. Suppt. to the 75th Ann. Rept. of the R.G. for England and Wales.

light mortality risk, it must first be considered whether the low mortality is not due to the selective recruitment of men of a high standard of fitness or alternatively whether there is not a selective discharge from these occupations of men whose health has deteriorated under the strain of their work, and who thus, passing out of observation, relieve the occupations of some part of the mortality which should statistically be debited to them."

The possibility of the opposite effect of selection by the overloading of comparatively light occupations with people of low physical health is equally to be considered. To get a direct measure of how far this selection exists in any particular case, and to what extent and in what direction it modifies sickness figures is not easy, though we may be confident that at any rate we have now no industry of which it could be said as it was of the " coal whippers " only 83 years ago—" Their sicknesses are generally short. In most cases they are so ill-prepared to bear sickness that they are cut off very rapidly, and die comparatively young."* However important this factor of selection may be in tracing causes, it does not obscure the figures from the point of view of the need for special precautions against any particular disease that shows itself in excess in any industry. If one trade for instance attracts phthisical people, however innocent the occupation may be as the original cause of the disease, it is not thereby relieved of the necessity for special precautions against this disease in the conditions under which the work is carried on.

We will leave out of account secular comparisons of occupational sickness from the earlier tables compiled from insurance records, since it is generally agreed that differences in the type of members and in the administration of the societies render such comparisons of small value for the purposes we are considering.

We have still, however, to face the fact that there are many divergencies between different processes in the same manufacture, and in different factories as well as at different times. As Arlidge† pointed out, " a modern manufactory is no longer the producing sphere of a simple article, but the centre for miscellaneous trades, having as many varied health features." Take a soap factory, for instance, and contrast the conditions of the men who deal with the unsorted masses of animal fat and other material as it comes into the factory, with those of the men in the chemical laboratory preparing the scent and dye that is going into the soap, or of those who make the wooden or cardboard boxes for the final packing. As Arlidge says, " The same difficulties beset comparative investigations made concerning all occupations, and especially do they abound in mining operations, in which the variations in health conditions in different pits, worked for the same minerals, surpass in degree and in kind those witnessed in factories.‡"

* Report of the Poor Law Commission, 1842.

† Diseases of Occupations, p. 60.

‡ loc. cit. p. 59.

In such material we have either to have recourse to very broad classification, broad enough and covering enough numbers to make our occupational classes—unhomogeneous in composition as each may be—at any rate homogeneous in time as regards their own composition, by which method only very decided tendencies could be expected to show themselves; or to adopt intensive enquiry over a limited field taking account of all sub-occupations and differing conditions, an apparently more promising method of bringing out health differences, but one which needs much time and co-operation to carry out, and at once brings in the difficulty of small numbers.

The age distribution of the population at risk is, of course, an important factor. There is no difficulty on this point with insurance figures, as the ages of all members are known, but in particular enquiries covering special occupations or districts where the information is obtained direct from the industry it is not always obtainable; for instance, in the recent investigation on Miners' "Beat Knee," "Beat Hand," and "Beat Elbow,"* the age incidence of cases was known, but for an approximation to the age distribution in the different occupations at risk, recourse had to be had to the Census figures.

In sickness statistics, as in those of mortality, simple rates by ages will generally tell us more of causal conditions than any single constant such as a crude or standardised rate. For other purposes, actuarial, financial or economic, a composite rate of this kind such as a price index number, may be essential or convenient, but it is generally true that for purposes of research to cloak the several variations of different factors under the garment of a single parameter is to lose more than we gain, and that the combination of unhomogeneous variables will never make up for want of numbers in the several groups.

If we turn to hospital or other institutional records for our sickness figures, the population at risk is vastly more indefinite. How are we to define exactly the area or class of people served? The population at risk here is clearly not even the same for different types of illness, so that we cannot even resort to the much-used but always dangerous method of comparative rates. This is, of course, still referring to the search for a general standard of ill-health. For particular purposes and the study of individual cases of disease, no one will deny that hospital records may furnish invaluable data.

Also affecting the population at risk in a way analogous to that of industrial selection, are questions of local environment, such as housing, etc. Industries are often intimately connected with certain local conditions, and to disentangle the effect of such conditions from the effect of the work itself is not always possible. Here, though, it may perhaps be argued that if the industry

---

* Special Report No. 89 of the Medical Research Council by Prof. E. L. Collis, M.D., M.R.C.P., and T. L. Llewellyn, M.D.

necessarily entails living in this outside environment any ill effects on health due to this cause may fairly be debited to the industrial account.

Let us go back now to our first question; what do available figures actually measure, and what is it that we really want to measure? We must remember that no single definition of sickness is going to suit all purposes. The only kind of sickness of which insurance records give us any measure is that causing incapacity for work—not for work of any kind, but for work similar to that on which the individual is usually employed—a very different matter.

That is all that the insurance society is concerned with, and for certain definite purposes, such as reckoning the economic cost in benefit, or loss of wages or time, this may be a very satisfactory measure. But for enquiring into the general effect of different industries on health and for tracing the causes of such effects, it is by no means so easy to interpret. Even if we steer clear of the minor fallacies that may arise from purely technical points of detail (e.g., that such sickness excludes the first three days of illness, that there is a waiting time before benefit is available, that unless a minimum time has elapsed meanwhile two consecutive sickness claims are counted as one, that sickness benefit is separately recorded from disablement benefit so that exclusion of the latter would entail exclusion of the more chronic cases, etc.), we are up against the difficulty that exactly the same physical condition in two different people, or even in the same person at different times may give rise to a sickness benefit claim in one case and not in the other. For example, the same attack of rheumatism that would prevent a miner at the coal face from working might allow a sedentary worker in a light occupation to carry on in spite of it. Apart from the actual physical conditions, sickness claims are also affected by many personal factors both psychological and economic. The amount of sickness recorded in any society or branch must to some extent depend on the stringency of the administration and also the relative facility for getting medical aid.

Quite apart from deliberate fraud or malingering, we still have the same human tendency of which a primitive example is thus described by Sir J. Frazer:—"Among the Gallas, when a woman grows tired of the cares of housekeeping she begins to talk incoherently and to demean herself extravagantly. This is a sign of the descent of the Holy Spirit Callo upon her. Immediately her husband prostrates himself and adores her she ceases to bear the humble title of wife and is called "Lord," domestic duties have no further claim on her and her will is a divine law."*

It is well known that any bad economic conditions—periods of long unemployment, strikes, lockouts, etc., as well as the relative difference between wages and sickness benefit, or

* "The Golden Bough," p. 98. Abridged edition.

compensation in the case of scheduled disease—have a decided effect on sickness claims. The course of the real incidence of a particular disease may thus be masked by changes in both economic and psychological conditions. For example, the two recent reports of the Miners' Nystagmus Committee* show that considerable increase in the reported cases of Miners' Nystagmus followed the scheduling of the disease under the Workmen's Compensation Act in 1907, and also that in many cases the psychological element largely predominates owing to the wide interpretation placed on the definition of the disease in the schedule. In some occupations, too, certain jobs are done by team work, and the pay shared among the workers in the same group, and this might tend to make a man keep away longer than necessary when fit for part work to avoid letting the others suffer by his low output.

One need not be either a physician or a psychologist to see that there is a very wide borderland between sickness and health, and that the most conveniently available division for statistical purposes—incapacity for work as judged by a benefit claim—places many people in the wrong territory in both directions. Unfortunately, too, under industrial conditions these misplacements are apt to be biassed one way or the other, so that we cannot count on their averaging each other out.

From a statistical point of view, sickness is an uncommon quality, and also a very variable one, so that the number of people observed needs to be large before reliable differences can be expected to appear. Hence it is a continual choice of two evils, numbers too small for decisive results on the one hand, or an unhomogeneous population on the other. For the present, at any rate, it seems as if comparatively small numbers were the lesser evil of the two, and that intensive enquiries of the sampling nature, devoted to a definite limited question, such as that now projected into the relative health conditions of humid and dry sheds in the cotton weaving industry, or the one now in progress into the variations in Miners' Sickness in different pits, are more likely to give useful results than more ambitious schemes aiming at establishing general health standards.

Since we are considering pitfalls and fallacies at least a passing reference must be made to the old but constantly recurring dangers of assuming that association necessarily implies causation, as in sickness statistics opportunities for it abound. An example of a pair of variables in which high correlation can be shown, held up as a warning by Professor Karl Pearson to his students, is that of the secular course of expenditure on the Navy and the consumption of bananas; Dr. Greenwood adds, ability to speak Dutch and low mortality from cancer of the breast. Mr. Hope Jones gives us the amount of calcium in our bones and the number of nephews and nieces we have, and Professor Raymond Pearl has unearthed one which was at one time made in all seriousness by a German writer—the occurrence of diphtheria and eating potatoes.

* Medical Research Council's Special Report Series Nos. 65 and 80.

Increasing familiarity with modern statistical methods is, however, slowly but gradually reducing the numbers of those who seem to think that a correlation coefficient is a substitute for common sense. Hardly less dangerous also than the practice of at once translating association into causation is the opposite error of ignoring an association because it obviously is not explained by direct causation. The association in even the most far-fetched of the above cases has *some* explanation, and if we had no other knowledge, or less knowledge than we have, about the variables concerned, might be a useful clue to follow.

In industrial sickness statistics the interpretation of admitted associations is often not clear. For instance, the same reports quoted above show that a definite association exists between the occurrence of Miners' Nystagmus and the use of safety lamps, but that how far this may be due to the effect of the type of illumination, and how far to the existence of psychoneurotic cases induced by other conditions, e.g., fear, associated with the type of pits in which safety lamps are used is not yet known.

All the points we have been considering have been made many times before by many people, the only excuse for going over them again now is that there seems to be an increasing demand for and interest in sickness statistics, and also that such statistics offer an obvious example of the fundamental principle often apt to be forgotten or obscured—that in attempting to estimate probabilities from statistical frequencies accurate consideration of all the known relevant circumstances comes first, and that the lack of it can never be compensated for by even the most elaborate mathematical treatment, but that nevertheless with all their imperfections such empirical estimates can be of great practical value.*

---

* "Utilissima est aestimatio probabilitatum, quanquam in exemplis juridicis politicisque plerumque non tam subtili calculo opus est, quam accurata omnium circumstantiarum enumeratione. . . . . Etsi autem empirice non posset haberi perfecta aestimatio, non ideo minus empirica aestimatio in praxi utilis et sufficiens foret." Leibnitz in a letter to Bernoulli, 3rd Dec. 1703 (quoted second hand from J. M. Keynes "Treatise on Probability").

E.—THE SIGNIFICANCE OF OUTPUT IN THE INVESTIGATION OF INDUSTRIAL EFFICIENCY.

By H. M. Vernon, M.D.

The criticism is sometimes raised that in industrial investigations too much importance is paid to the question of output. The workers themselves are inclined to resent output measurements, as they often imagine that they are being made at the express desire of the management. In their estimation the measurements appear to imply that their rate of production is too low, and ought to be speeded up. This suspicion on the part of the workers can usually be removed, or considerably reduced, by frankly explaining to representative workers the aim and object of the investigation. It is our usual custom, before starting observations in a workroom, to have a brief talk with the charge hands, and ask them to pass on the information to the other workers, and also to talk with the workers themselves whenever opportunity offers. Nevertheless, suspicion of output measurements is so ingrained in the minds of some of the workers that it seems to be worth while to examine briefly the use of output tests.

The Output Test.

Firstly, to what extent do investigations in industrial psychology and physiology, taken as a whole, depend on output tests? We must certainly admit that in many if not most of our investigations we attempt to estimate the output of the workers before and after the introduction of some change in working conditions. The reason of this procedure is that under ordinary circumstances output is the best indication we have of the health and efficiency of the workers. Granted that they are doing their best and are in no way restricting their output, we know that any steady improvement of output, must mean an improvement of the conditions under which the work is being carried on, whereby it can be prosecuted with greater ease. Better working conditions mean better health for the workers, and their increased output may be due chiefly if not entirely to their greater vigour consequent on improved health. The reality of this increase in health and vigour is supported by the fact that when any change is made in working conditions, it generally takes several months before the full response to the change is established. For instance, the writer found (Report No. 6.) that when men and women engaged in making various fuse parts had their hours of work reduced from about 74 a week to 64 a week, and subsequently to 55 a week, their working speed improved considerably with each reduction of hours, but it took three or four months before it attained equilibrium with the shortened hours. For the first week or two after the change of hours there was little or no response, and then the output—reckoned per working hour—began to mount up steadily, till finally it reached a point at which it more

than compensated for the loss of working time, and the total output each week was higher than before. Again, the writer, working in conjunction with T. Bedford (Report No. 25) found that when a 10-minute rest pause was introduced in the middle of the 4½ or 4¾ hour morning spell of work, the women and girls under investigation showed a 5 to 10 per cent. improvement of output, but it took them three to six months before they reached equilibrium.

These improvements of output are acquired quite unconsciously. The workers are making no more effort than before. In fact, they are making distinctly less effort, and yet they are achieving a better result. The "speeding up" induced by bettering the working conditions *never* connotes increased strain on the part of the worker, and the output tests employed by the industrial psychologist are always made with a view to improving the conditions of work and lessening fatigue. Perhaps the most striking application of this doctrine is met with in time and motion studies, provided that these are carried out on right principles. Both Taylor and Gilbreth made *speed* the primary object of their systems of standardisation. Taylor timed his quickest worker and utilised his time, to which a certain margin was added to cover unavoidable delays, as the standard time for the task. Gilbreth considered that the quickest movements were the best, and maintained that there is "one best way" for performing each of the separate movements into which a given operation can be resolved. This contention is illustrated by picturing what our leading exponents of cricket and golf would say if they were told that there was only one good way, to which all of them must rigidly conform, of performing the various strokes. Undoubtedly some of the methods of performing a job are essentially bad and others are good, but inevitably the *best* way is not the same for everybody. It varies with a man's stature, his physical strength, his quickness of reaction, and other attributes.

As has rightly been pointed out by Farmer (Report Nos. 14 and 15), the best way is the *easiest* way, in the sense that it leads to the least fatigue. The underlying principle of motion study should be rhythm not speed, and if time and motion study is undertaken with the object of reducing fatigue by the avoidance of unnecessary movements and by making the necessary movements simpler and more rhythmical, the output of the workers almost inevitably improves, in spite of, or rather because of, the diminished effort required. Farmer found that experienced women engaged on the process of polishing spoons and forks, when trained to perform their work by a standardised system of movements, were able to reduce the time taken by 8 to 40 per cent. Again, he found that groups of girls, when trained in the operations of chocolate packing, sweet bottling and sweet dipping, showed a marked improvement of output. The girls taught the new methods were for the most part fresh workers, as it was

found to be difficult to get experienced workers to change old-established habits, but in some instances the older girls, noticing the greatly increased earnings of the younger ones, spontaneously adopted the new methods.

The Existence of Overstrain.

During the earlier years of the war it is probable that the majority of our industrial workers were in a condition of considerable overstrain owing to the excessively long hours of work demanded, coupled as they were with Sunday labour. The folly of this overwork was recognised during the latter part of the war, and the hours of labour were usually cut down to about 55 per week. As Saturday afternoons and Sundays were generally (and rightly) kept free of work, it meant that a 10-hour day was worked for the rest of the week. Such a day was the rule in many industries before the war, and there can be little doubt that it often caused overstrain, especially in women. Since the war a 44 to 48-hour week has become almost universal, and it is probable that these shorter working hours have eliminated overstrain in the great majority of instances. It is impossible to obtain an unexceptionable proof of the validity of this contention, but the sickness data available strongly support it. During the war I collected sickness figures at three large National Shell factories for an 18-month period, during which the hours of work were changed considerably by the adoption of various two-shift and three-shift systems. The time lost by sickness and by other and avoidable causes was carefully separated, and it was found that the sickness time fell off steadily the shorter the duration of working hours. The women, when working for 62, 54 and 44 hours per week lost respectively 6·4, 4·3, and 3·1 per cent. of their time, whilst the men, when working for 62 and 54 hours per week, lost respectively 5·7 and 4·0 per cent. of their time. During the last three years Bedford and I have collected sickness data at several factories, and we have always found it to be less than the figures quoted. For instance, at a tin canister factory where nearly 1,000 women were employed, only 2·1 per cent. of working time was lost by sickness between September, 1922, and August, 1924, and at a large boot and shoe factory the women in 1922–1923 lost 2·5 per cent. of their time from sickness and the men 1·8 per cent. of it. At both these factories a 44-hour week was being worked. Again, so far as can be judged by personal inspection, the general health and cheerfulness of the workers is distinctly improved. Speaking from an experience extending over a wide range of industries, I can say that I have seen no indication of strain and tiredness, nothing of the relentless drive due to continued speeding up and overwork, which I sometimes observed during the war period.

Evidence of another kind was obtained by Bedford and myself in several industries (carton-making, labelling, shoe-making) where short time was in force (*cf.* Journ. Nat. Inst. Indust.

Psychol., 1924). The workers were usually on an 8-hour day, but when on short time they put in only 3, 3½, 4, 4½ or 5 days of work a week. We found that as the number of working hours increased, the speed of production increased likewise, till it attained a maximum with a working week of about 40 hours. With longer hours still it fell away, and it was 2 per cent. less (per working hour) when a 44-hour week was being worked, and 4 per cent. less with a 48-hour week. This rise and fall in speed of production appeared to be due chiefly to the existence of two conflicting factors. One factor is the long week-end rests which resulted from the short-time system. They induced some loss of manipulative skill in the workers, and such loss would be greater and greater the more numerous the working days missed. On the other hand, the other factor, fatigue, developed more and more as the working hours increased, but the comparatively small reduction of speed noted when passing from a 40-hour week to a 44 and 48-hour week suggests that not much strain was being put upon the workers.

Again, it may be maintained that industrial workers are liable to overstrain because of the monotony inevitable in much of the present-day repetition work, but I myself, in the course of a somewhat extended inquiry (Report No. 26), could obtain very little evidence that the women and girls objected to monotony, though the men occasionally did so.

Such overstrain as does exist in industry can often be appreciably diminished in a very simple manner. A 47 or 48-hour week implies an 8¾ or 9-hour day on most week-days, and on the one-break system this involves a morning work spell lasting 4½ to 5 hours. Bedford and I (Report No. 25) questioned whether the average girl or woman could maintain her full working efficiency for so long a time as this. We pointed out that many of the workers took half-an-hour or more to travel between their homes and the factory, so that by the time they got their dinner they might have been six hours without food. Such a long fast, coupled as it often was with strenuous and exacting work, would tend to induce a condition of overstrain. This could easily be avoided by allowing a 10-minute break in the middle of the morning, during which tea and a little food could be taken.

Though it seems probable that in the great majority of industries there is very little overstrain, and that such as does exist can for the most part be avoided, and it is not to be assumed that real overstrain does not occur in exceptional instances. Such instances may require special treatment, though usually a reduction of working hours or an increase in the number and duration of the rest pauses will effect a good deal of improvement.

Overstrain in Relation to Wage Payments.

It is probable that at the present time the most frequent cause of excessive speeding up, with resultant overstrain, is due to inadequate or unsuitable systems of remuneration. Most industrial workers desire to maintain a certain level of weekly

income and expenditure, and if their piece-rate payment is too low they may overstrain themselves in their endeavour to attain the wage they consider to be necessary. In such a case it is obvious that if their working conditions are improved as the result of psychological and physiological investigation, their overstrain will be diminished and not increased. If, on the other hand, their piece-rate is cut as the result of their improved output so as to reduce their earnings to their previous level, they rightly feel aggrieved, and acquire a rooted suspicion of all new methods which tend to an improvement of output. Still, they would probably be prepared to admit that if, in consequence of improved working conditions there was a considerable improvement of output, it is only fair that it should be shared between the employer and the employed. This brings us to the question of rate-fixing, a subject which is outside the province of the Investigators to the Board. It is permissible, however, to make a brief quotation from the book on "The Wages of Labour," written by the Chairman of the Board, in which he says: "It is surely obvious that the task of rate-fixing must be undertaken jointly by employers and employed. Under no other circumstances is payment by results likely to secure a fair trial."

Conclusions.

The main conclusions arrived at are two in number. Firstly, that so far as evidence is available, it appears that nowadays industrial workers seldom suffer from overstrain as the result of excessive speeding up. Secondly, that if the workers in certain occupations are really suffering from overstrain, they ought to be the first to welcome the advent of the industrial psychologist, even though he usually employs output tests in the course of his investigations. His main object is to improve the working conditions and thereby reduce over-fatigue. He does not specially aim at increasing output, though an increase of output almost inevitably results if he is successful in his attempt to better the conditions.

F.—ON PERSONAL EVIDENCE AS DATA.

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

The application of scientific methods to the study of the reactions of industrial workers to factory conditions and the attempts consequently made to obtain objective proof of the nature and extent of such reactions, have perhaps tended to overshadow the importance of the direct personal evidence of the workers themselves in inquiries of this kind. Yet in many of these inquiries the testimony of the workers is a necessary part of the data required. Not only is such evidence valuable for explaining trade habits, traditions, and other special circumstances affecting methods of work, and for informing the investigator of the nature of subjective experiences (whether associated with the normal conditions of work or with any experimental conditions established), but it will often facilitate delimitation of an inquiry and direct attention to the most important aspects of it. Without such evidence it is not unlikely that much time may be spent in collecting data of secondary importance, or data which will yield only negative conclusions.

The evidence of the workers may also be necessary to explain facts disclosed by observation and experiment, or to corroborate inferences drawn from these facts, and to support conclusions suggested, but inadequately proved, by other data. The conditions under which investigations in factories are made are often so variable, that the data obtained are too ambiguous to justify any conclusions sufficiently definite to be of any practical value, unless the evidence of the workers can be used to determine their probability.

The interpretation of individual work curves, and of curves plotted from records of the performance of a few individuals, may be exceedingly difficult and unreliable, if it is attempted without the aid of any relevant information obtainable from the individuals concerned. The work curve which is based on mass data presents less difficulty in this respect, as any very marked features will probably be due to important factors which are known to be in operation. The general characteristics of most work curves show a resemblance to a basic curve, the shape of which is considered to be determined by general factors such as, incitement, settlement, spurt, and fatigue, their particular shapes being determined by variations of these factors and by the operation of special factors such as, temperature, ventilation, lighting, hours of work, rest pauses, etc., the effects of which are superimposed upon those of the general factors. About the subjective feelings experienced by the workers during periods in the daily factory life when these general factors are operative, we really know little. Yet if these factors are to be understood in anything but a vague way, we cannot afford to neglect introspective evidence which only the worker can supply.

Exceedingly interesting results might be obtained if, coincident with hourly output records taken on a fairly large scale under actual factory conditions, the workers were asked to make, at similar intervals, brief records of their feelings of fitness, boredom, rate of working, etc., so that these could be summarized and subsequently considered in the light of the objective indications of the output curve. Some experiments along these lines have been made by Muscio* with instructive results, but a more extended investigation in a factory would probably be well worth while.

To obtain the personal information desirable for the proper study of problems connected with the human element in industry is not always so simple a matter as may be supposed. It calls not only for those qualities which are generally understood by the term "tact," but also for a certain special technique.

It is perhaps stating the obvious to say that the first consideration of the investigator should be to set his prospective "witness" at ease—to dispel any awkward restraint, and to create an attitude of intelligent interest by explaining the object of his inquiries. The attitude of the workers towards one who enters a factory with the object of making a scientific study of the prevailing conditions may vary very much—from amused tolerance to excessive awe, from cynical scepticism to open hostility—so that no little resource and patience may be required to deal with them successfully. The man who knows a great deal about his job and can give much useful information, not only concerning the character of the work, but also as to its effects upon the worker, may be very willing to share his knowledge, or he may be distrustful, and even truculent, and obviously determined to keep what he knows to himself. If he is of the latter type, he may still respond to leading questions, or to assertions designed to provoke denials which may often be accompanied by explanations containing just the information it is desired to obtain. Fortunately, this type of person is not often met with, and it is seldom that his evidence cannot be duplicated by others more willing to give it.

There is a fairly large class of worker from whom it is difficult to obtain any positive data because they are indifferent to many of the circumstances of their factory life. Some of these are the "square pegs" of industry, others are of the type which welcomes work of a monotonous character. An apparently casual conversation will often elicit from them more useful information than could be obtained by direct interrogation. On the other hand, some workers think much about the conditions of their work and are anxious to give all the information they can. People of this type, of course, are sometimes those who hold strong, but not always sound, views which they are anxious to propagate. Their evidence, however, is usually most instructive, and I have received very interesting letters from some of them whom I have had no opportunity of questioning.

---

* "Feeling-tone in Industry." B. Muscio. Brit. Jour. Psy. (General Section) Vol. XII, part 2, pp. 150–162. Oct. 1921.

The form in which a question is put has an important bearing on the nature and value of the reply received. This fact is well understood in legal practice, and has given rise to rules governing the use of leading questions, which should be carefully observed when interrogating workers if the data obtained from them is to be really reliable. One has heard employers and managers put to their workers such a question as, " Don't you feel less tired since your table has been raised ? " The usual reply has not unnaturally been " yes," since, when no strong contrary feeling exists, this is the reply most likely to be evoked by a question obviously suggesting that an affirmative reply is expected. Sometimes the existence of a relation between the querist and the person questioned, as that of employer and employee, will further tend to bias replies given to questions put in this form. The reply quoted is of little value because one cannot be certain whether it is an expression of considered opinion, or merely reaction along the line of least resistance. It is clear that if a question permits of alternative answers it should be put in a form which does not unduly suggest anyone of these alternatives. Thus, the question discussed might fairly be expressed as, " Since your table has been raised do you get more or less tired than you did before ? " Probably, however, a better question would be one couched in more general terms, such as, " How has the raising of your table affected you ? " because the more specific question implies that the alteration is expected to have affected only feelings of fatigue. A general question may produce a greater number of indefinite replies than a specific one, but, on the other hand, such positive replies as are received will probably be more informative, and almost certainly more reliable, because they are likely to be elicited only if the point in question has received due consideration. Questions directed to particular effects can always be used subsequently if the general question is not properly understood, or if it fails to elicit all the information required. The use of leading questions is only justified when it is clear that those to whom they are put are not likely to be influenced by suggestion ; but, as a general rule, questions should be carefully framed so as to avoid any suggestions likely to prompt the reply.

In a court of law the best possible evidence is the direct oral testimony of witnesses having personal knowledge of facts relevant to the issue. Some of the reasons for this are that the court can satisfy itself that the evidence given is as complete as possible, is rightly understood, and is obtained fairly and from persons competent to give it. For similar reasons it is usually best, as well as most convenient, to obtain evidence from workers orally, though, of course, in inquiries of the kind here considered, such evidence, whether oral or written, is not always the best evidence from which to draw conclusions. It is obvious, however, that if the oral method is used it is easy to amplify and explain any questions which are not properly understood and similarly to clear up any doubt as to the precise meaning of replies received.

In certain circumstances, as when the correlation between judgments of the workers or subjects and experimental observations is to be tested, or when the statements of workers must be relied on as the principal or substantial part of the data, written questions are desirable. Questionnaires have seldom been submitted to the workers in factory investigations, and of course unless the questions are very carefully drafted, conclusions based upon the replies may be of very doubtful validity. This method, however, has the advantage of enabling a careful analysis to be made of all the replies received, whereas by the oral method the investigator is likely to retain only those which have impressed him most, either on account of their frequency of occurrence, or on account of their exceptional character. A questionnaire which is to be given to factory workers should be as simple and short as possible, and should be drafted in such a way that it can be answered quickly and without difficulty, so that the interest of the worker is not taxed sufficiently to result in more or less thoughtless and useless replies. The best way to do this, as a rule, will be to set out the possible alternative replies and ask the worker to strike out those which do not express his answer.

A development of the questionnaire method which can usefully be employed in certain cases (as, for instance, when a continuous check is to be kept on variable factors likely to interfere with the interpretation of performance test data) consists of a special diary containing suitable questions for each day it is required to be kept. This method has been successfully used during an investigation carried out in a cotton mill* and, if the necessity for it is properly explained to the workers, it is unlikely that any difficulty will be experienced in securing their intelligent co-operation. An example of a carefully drafted questionnaire is that used by Galton in his inquiry on visualising,† and another of a simpler kind, and more suitable for factory use, has been employed by Muscio.‡

Judgments of fatigue based on subjective feelings are known to be often unreliable and not in agreement with objective records, but we are not justified in leaving them out of account merely because their correlation with output is imperfect. A large number of them, obtained from factory workers, will have to be studied before their practical significance can be fully appreciated. Interest and incentive connected with the work have much to do with such judgments. If, for instance, a worker has no feelings of fatigue when it is known that his output is falling, it may be that actually he is fatigued but is too absorbed in his work to become aware of feelings of weariness. On the other hand, of course, it may be true that he is not fatigued and

* "A Performance Test under Industrial Conditions." S. Wyatt and H. C. Weston. Brit. Jour. Psy., Vol. X, part 4, pp. 295–297. July 1920.

† "Inquiries into Human Faculty." Francis Galton, F.R.S. J. M. Dent & Sons, Ltd. Appendix E, pp. 255–256.

‡ "Feeling-tone in Industry." B. Muscio. Brit. Jour. Psy. (General Section), Vol. XII, Part 2, pp. 153–156. Oct. 1921.

his falling output may be due to deliberate restriction dictated by special motives. Conversely, when a worker complains of feeling tired but his rate of output shows no change, it may be that his interest is failing, though his habitual rate of working is unaffected, at any rate for a time. In such a case the quality of his output may suffer, but it seems that his " tired " is really synonymous with " bored," and in many cases it is justifiable to interpret " tired " in this sense. It is known, however, that an increase of output may occur when fatigue is present, not only as the result of various incentives, such as the desire to finish a particular piece of work before " knocking off " time, but also as a result of impaired control, a condition which may also increase the liability to accident.

Sensations of " fatigue," of sufficient intensity to be recognised as such, probably occur some time before any physical conditions which underlie them develop sufficiently to produce a noticeable reduction of working capacity. These sensations seem to be defensive, to give a warning which ultimately becomes insistent enough to lead the worker to rest before serious fatigue ensues; and the study of human behaviour in industry would be incomplete if they were ignored. It seems probable, however, that the discrepancy often observed between subjective feelings and objective indications of fatigue may be more apparent than real, and that it may be due in some degree to the type of question put to the worker for the purpose of discovering his feelings. Various sensations may influence the worker in coming to the decision that he is " tired." The average worker is unaccustomed to careful self-analysis, and is unaware of the ease with which his judgment can be deceived by factors tending to complicate comparison and to obscure the real issue he has to decide. For this reason, questions calling for a direct judgment such as " tired," are insufficient by themselves to enable the presence or absence of fatigue to be inferred.

Questions relating to interest or incentive, effort and speed are also necessary in order to check the workers' judgment. To determine the value of judgments of relative speed of working it is essential to obtain information relating to factors which may have influenced the worker in forming his opinion. Such judgments are determined not only by visual sensations of movement, but by memories of previous impressions of speed, by awareness of temporary hindrances and the emotional disturbance they may occasion, by sensations of effort, and probably by other vague and variable impressions. Subjectively, consciousness of extra effort exerted at a particular time in executing given movements may often give the illusion of extra speed, and similarly the illusion of reduced speed may occur owing to the disproportionate consideration given to trivial disturbances merely on account of the emotions they excite.

However, to obtain useful information as to the sensations which underlie some of the statements made by workers is not

always easy, and it may be necessary to describe to them a number of sensations and to ask them to indicate which of such descriptions most closely resembles their own feelings.

Questions on fatigue which can be referred to specific groups of muscles, observed to be extensively used in any particular occupation, are not infrequently met with negative replies. It cannot, however, be inferred from these that the work is not fatiguing, because there may be fatigue of other muscles which are not apparently used. Thus, a man standing for long periods at a machine which he manipulates with his hands may experience acute fatigue of the muscles of the legs, which are kept rigid, long before he notices that his hands and arms are tired. Similarly, certain workers in the leather trade who have to adopt a tense and rigid attitude experience fatigue in the loins, though they do not complain of their hands and arms, which are actively employed in their work. Static fatigue, of which the foregoing are examples, is not disclosed as such by output records, nor is it usually possible to estimate its importance in any particular occupation without the direct evidence of the workers themselves.

It may, then, be unsafe to infer the presence or absence of fatigue, and of other effects due to factory conditions, either from the output curve or from statements of the workers alone. The whole of the evidence, objective and subjective, should be considered together, and the reliability of the latter is sometimes equal to that of the former, when all the circumstances which may affect output are taken into consideration. In any case, whatever actual relation may exist between subjective feelings of fatigue and diminished physical capacity for work, it seems certain that practically, under modern conditions of relatively short hours, the feelings of the workers will often play a more important part in determining variations of the rate of output than will fatigue in the popular sense of the term. So long, therefore, as we have no direct method for the exact measurement of fatigue, the personal evidence of workers should not be neglected nor its value as data underestimated.

SUPPLEMENT.

LIST OF REPORTS AND OTHER PUBLICATIONS.

I.—Reports of the Board.*

Note.—The following pages contain a complete list of the Reports of the Industrial Fatigue Research Board published up to March 31st, 1924. For convenience, they have been grouped in series according to the particular industries to which they relate, but it should be pointed out that the whole of the work of the Board has a common foundation, and results discovered in one industry may often have a direct bearing on others.

General and Miscellaneous.

First Annual Report of the Industrial Fatigue Research Board to March 31st, 1920. (31 pages). [Price 6d. net, post free 7½d.]

[An account of the origin of the Board, the methods of research employed, and the investigations undertaken.]

Second Annual Report of the Industrial Fatigue Research Board to September 30th, 1921 (with Analysis of Published Work). (65 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[Part I contains a review of the work carried out during the 18 months ended 30th September, 1921. Part II consists of an analysis of the published work of the Board arranged on a systematic plan, with full references to the separate reports.]

Third Annual Report of the Industrial Fatigue Research Board to December 31st, 1922. (83 pages). [Price 2s. net, post free 2s. 1½d.]

[Part I contains an account of the investigations and researches completed during 1922, and contemplated during the current year. Part II consists of personal contributions from investigators, dealing with different aspects of the work and also with specific problems calling for inquiry in the cotton and pottery industries.]

Fourth Annual Report of the Industrial Fatigue Research Board to December 31st, 1923. (65 pages.) [Price 1s. 3d. net, post free 1s. 4½d.]

[An account of the activities of the Board during 1923. A special section is devoted to personal contributions from Investigators to the Board dealing with different aspects of the work.]

---

* The Reports issued by the Board can be purchased from H.M. Stationery Office at the following addresses :—Adastral House, Kingsway, London, W.C.2, and 28, Abingdon Street, London, S.W.1 ; York Street, Manchester ; 1, St. Andrew's Crescent, Cardiff ; or 120, George Street, Edinburgh ; or through any Bookseller.

The offices of the Board are unable to supply them directly.

Applications by post to the above addresses should quote the descriptions in full of the publications wanted, and should be accompanied by the price as indicated in the list.

No. 27.—Results of Investigation in Certain Industries. 1924. (15 pages). [Price 6d. net, post free 7½d.]

[A synopsis of the results of investigations promoted by the Industrial Fatigue Research Board in various industries, including the textile, metal, boot and shoe, pottery, glass, and laundry industries, and light repetition work. The results have been grouped under the headings of working conditions, working methods, and administrative and miscellaneous questions for each industry respectively, and references to the original reports where the full data are given are inserted in the text.]

No. 4.—The Incidence of Industrial Accidents upon Individuals with special reference to Multiple Accidents, by MAJOR GREENWOOD, M.R.C.P., and HILDA M. WOODS. 1919. (28 pages). [Price 6d. net, post free 7½d.]

[A contribution to the study of the causation of accidents, based on a statistical investigation of certain accident records kept by the Ministry of Munitions. The results indicate that accidents are largely due to a special susceptibility inherent in the personality of the individual, so that the bulk of accidents occur amongst a limited group of individuals, and that the incurring of one accident is in itself of minor importance in connection with the probability of incurring a second or subsequent accident.]

No. 6.—The Speed of Adaptation to altered Hours of Work, by H. M. VERNON, M.D. 1920. (33 pages). [Price 1s. net, post free 1s. 1½d.]

[The report compares, by means of data derived from previous investigations and of others hitherto unpublished, the speed with which workers in different occupations adapt themselves to altered hours of work, and shows that whereas any increase in hourly output resulting from reduction of hours is gradual, in the converse case of a decrease in hourly output due to lengthening of hours the effect is immediate. A further important point, emphasising the interdependence of occupations in a factory system and indicating that reduction in hours may be fruitless unless an operation is considered in all its bearings, is brought out by the fact that in certain engineering processes the hourly output of women operatives working on short hours with the men tool-setters and labourers working on long hours was less than when the men's hours were diminished and the women's increased.]

No. 12.—Vocational Guidance (a Review of the Literature), by B. MUSCIO, M.A., Investigator to the Board. 1921. (57 pages). [Price 1s. net, post free 1s. 1½d.]

[A critical survey of the literature on the subject with bibliography.]

No. 13.—A Statistical Study of Labour Turnover in Munition and other Factories, by G. M. BROUGHTON, M.A., ETHEL M. NEWBOLD, B.A., and EDITH C. ALLEN. 1921. (88 pages). [Price 3s. net, post free 3s. 2d.]

[The report deals with the labour turnover (*i.e.*, the rate of change in the working staff) between the years 1916 and 1920 in ten munition and three other factories, and is based largely on the employment records already available at the Ministry of Munitions. It points out the advantages

of periodical revision by employers of the state of labour turnover in their factories. The necessity of adopting some method of estimating labour turnover is urged, since a slight wastage may remain entirely undetected, and if unchecked will involve a serious waste of time on the part of both employers and employee. Labour turnover may also be used to indicate to some extent internal conditions in the different departments of a factory. A test is explained, which indicates whether wastage is unduly high and calls for futher investigation as to the cause, and notes on factory records and record keeping are included.]

No. 14.—Time and Motion Study, by E. FARMER, M.A. 1921. (63 pages with plates). [Price 2s. net, post free 2s. 1½d.]

[Part I consists of a critical review of the past work on the subject, including Taylor's and Gilbreth's methods. Part II is an account of a series of experiments carried out by the author in a confectionery factory, in which motion study was applied, not to determine the movements which took the shortest time to perform, but to discover those movements which when properly learned the worker would find easiest to perform. The results obtained in two manual processes showed increases in output of 27 and 88 per cent. respectively. The report includes photographs showing the needlessly large number of movements used by untrained workers, and the improvement following a short course of training. A full bibliography, including references to periodicals, is appended.]

No. 16.—Three Studies in Vocational Selection, by B. MUSCIO, M.A., and E. FARMER, M.A. 1922. (86 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[Part A (The Psycho-Physiological Capacities of Hand Compositors) describes an investigation on vocational selection conducted amongst hand compositors in printing works. After close observation of the work and of the particular capacities demanded, tests which seemed to be prima facie suitable were selected and applied to two groups of about 25 compositors. The subjects were then graded first according to the marks obtained in the tests, and secondly, according to the actual working proficiency shown by each, and the two gradings compared. Such tests as were shown to be unnecessary were then eliminated and a grading based on the remaining tests correlated with the proficiency grading. In this way, the high correlation co-efficients of ·80 and ·71 were obtained for the two groups.

Part B (The Measurement of Strength with reference to Vocational Selection) is concerned with the physical side of vocational selection, and is based on observations of the range of muscular strength amongst about 2,300 youths in Manchester and industrial Essex. The results show first that a combination of grip and weight gives a useful indication of general muscular strength, and secondly, that there is a consistent difference between youths of the same age in the two localities.

Part C (Physical Measurements in a Confectionery Factory) is an account of a somewhat similar investigation, based on the finger and hand measurements of girls in a confectionery factory. The results show that two distinct types exist, designated long-spanned and short-spanned, and that each of these types is specially prevalent in certain occupations, suggesting that the former type is desirable for some kinds of work and the latter for others. A more intensive treatment of the data led to rather indefinite results, probably because other and more powerful factors in proficiency tend to mark the influence of physical type.]

No. 19.—Two Contributions to the Study of Accident Causation, by ETHEL E. OSBORNE, M.Sc., H. M. VERNON, M.D., and B. MUSCIO, M.A. 1922. (xi and 36 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[Part A (The Influence of Temperature and other conditions on the Frequency of Industrial Accidents) is based on observations carried out during the war in certain munition factories in which accurate records of accidents of all kinds were kept. The results indicate that there is a minimum frequency of accidents at a temperature of about 67·5°F., and that both above and below that temperature accidents tend to increase in number. The ultimate subjective causes of accidents are also discussed, and from a comparison of the day and night incidence the conclusion is reached that speed of work, the psychical state of worker, and, in some instances, fatigue all play a part.

Part B (On the Relation of Fatigue and Accuracy to the Speed and Duration of Work) is an account of a laboratory research undertaken in order to determine to what extent accuracy of movement is affected by (*a*) speed of work, and (*b*) fatigue as measured by the duration of work. The results, which are admittedly only tentative, indicate that the former is the important factor, since accuracy diminishes as the speed is increased, but actually increases over a continuous spell of work at a constant speed.

The preface to the report contains a short analysis of the work carried out on the personal side of accident causation.]

No. 28.—The Function of Statistical Method in Scientific Investigation, by G. UDNY YULE, C.B.E., M.A., F.R.S. 1924. (14 pages.) [Price 6d. net, post free 7½d.]

[Describes in popular language the uses and limitations of statistical methods in investigations of the kind carried out by the Board.]

No. 29.—The Effects of Posture and Rest in Muscular Work, by E. M. BEDALE, M.A., and H. M. VERNON, M.D. 1924. (55 pages, with plates). [Price 2s. 6d. net, post free 2s. 7½d.]

[This Report contains the results of two investigations on muscular work. In the first of these, eight common methods of weight-carrying are compared. It is shown that these have a definite order of merit, as demanding different expenditures in the chemical exchanges of the body, and that these physiological "costs" are related to physical causes, particularly to the degree to which the body's normal centre of gravity is displaced.

The second investigation deals with effects of maximal effort in lifting and pulling, etc. The principal points that emerge are, first the existence of an optimum height from the ground at which the greatest effort can be exerted, and of a "weak spot" nearer the ground, secondly the beneficial influence of changes in posture on the maintenance of pulling capacity, and lastly the beneficial influence of rest-pauses interpolated between the pulls.]

Metal Industries.

No. 1.—The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture, by H. M. VERNON, M.D. 1919. (31 pages, with plates). [Price 6d. net, post free 7½d.]

[Compares the fatigue and output of mill-men working on shifts of four, six and eight hours, and in factories with different systems of ventilation, the data being obtained partly from existing records and partly by direct observation. The results show that for this particular work when an eight-hour shift was reduced to a four-hour shift the hourly output eventually increased by 11·5 per cent. Similarly on a six-hour shift the hourly output increased by about 10 per cent. compared with that on an eight-hour shift, corresponding to a rise of 8·3 per cent. in total weekly output. The existence of a seasonal variation in output is shown, and attention is drawn to the marked effect of good ventilation on fatigue and output, efficient ventilation probably increasing the average output of an unventilated factory by 12 per cent. or more. Suggestions are also made as to suitable clothing for the work.]

No. 2.—The Output of Women Workers in relation to Hours of Work in Shell-making, by ETHEL E. OSBORNE, M.Sc. 1919. (23 pages). [Price 6d. net, post free 7½d.]

[Embodies the result of a small investigation based on the booking of hourly output of 43 women engaged in shell-turning during one week on two twelve-hour shifts and during one week on three eight-hour shifts, and compares the fatigue and output under the two systems.]

No. 3.—A Study of Improved Methods in an Iron Foundry, by C. S. MYERS, C.B.E., M.D., F.R.S. 1919. (8 pages). [Price 2d. net, post free 3d.]

[A short description of the methods adopted in an iron foundry with the full concurrence of the workers, the introduction of which greatly increased the output for jobs that included machine work.]

No. 5.—Fatigue and Efficiency in the Iron and Steel Industry, by H. M. VERNON, M.D. 1920. (99 pages, with plates). [Price 3s. net, post free 3s. 2d.]

[This report is based on investigations of numerous iron and steel works situated in England, Scotland and Wales, where all the workers are now on eight-hour shifts, though in certain districts they were on twelve-hour shifts until recently. It shows that as a result of the reduction of hours, the output from the open hearth steel furnaces went up 2 to 9 per cent., but that there was no change in the output from the rolling mills or the blast furnaces. The timekeeping of the blast-furnace men, however, improved, and it was found possible to reduce the number of men required to run the furnaces.

The effects of fatigue were specially seen in the blast-furnaces men on Sundays, when they worked a sixteen-hour shift, their rate of charging the furnaces (by hand) being 5 to 10 per cent. less than on weekdays, when they worked eight-hour shifts. Again, the rate of charging was 16 per cent. less in the summer than in the winter, and seasonal variations in the output of the heavy workers were likewise observed at the steel furnaces, the puddling furnaces and the rolling mills. Practical suggestions are made for reducing the heaviest work of all, namely, that of the steel melters when fettling (*i.e.*, mending) their furnaces. An attempt is also made to classify occupations according to the fatigue of the work.

Sickness and mortality data relating to 24,000 iron and steel workers were tabulated for a six-year period. Men on the heaviest work experienced the most sickness, the steel melters showing 23 per cent. more than the average, the puddlers 20 per cent. more, the tinplate mill-men 12 per cent. more, and the rolling mill-men 8 per cent. more. The excess of sickness shown by the puddlers was due entirely to rheumatism and respiratory diseases. The steel melters showed 26 per cent. greater mortality than the average, and the blast-furnace men a higher mortality still.]

No. 15.—Motion Study in Metal Polishing, by E. FARMER, M.A. 1921. (65 pages, with plates). [Price 2s. net, post free 2s. 1½d.]

[The report describes the effect of applying time and motion study to various processes in a factory where the buffing of spoons and forks is carried on, but the results are applicable with slight modification to all processes of grinding or polishing by means of a revolving wheel. At the beginning of the investigation there were enormous differences in the movements and methods of the workers, and corresponding differences in the amount of wasted energy expended. An attempt was therefore made to systematise the effort required for each process, based in some degree on the methods adopted by the most efficient workers present. The slower and less efficient workers were then trained to adopt the standard method. As the result, the time required to perform a standard task was reduced by 8 to 61 per cent. in one process, and by an average of 30 per cent. in another.

Data are given to show that a beginner, given adequate training, can become an expert worker in a few days, but that left to herself without proper instruction she probably will never become highly skilled and will continue all her life to waste her energies in unnecessary and unproductive movements. The report also contains information on the effect on output of rest-pauses and of the provision of seats for the workers.

Finally, a method of measuring the duration, number and pressure of the strokes used by the workers is described, and the importance of these factors on ease of working is discussed.]

Textile Industries.

No. 7.—Individual Differences in Output in the Cotton Industry, by S. WYATT, M.Sc. 1920. (13 pages). [Price 6d. net, post free 7d.]

[Embodies the results of a small preliminary inquiry based on individual differences in output in various processes in the cotton industry as measured by the variations in piece-rate earnings, and illustrates the extent to which in each process production depends on human, as opposed to mechanical, efficiency.]

No. 8.—Some Observations on Bobbin Winding, by S. WYATT, M.Sc., and H. C. WESTON, M.J.Inst.E. 1920. (40 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[A full description of the conditions prevailing in the winding department of a certain mill, with rather special features. The various factors directly affecting efficiency in winding are discussed at length, and the operations involved in bobbin-winding are analysed into their elementary movements. Finally, the relation of machine design to fatigue is illustrated.]

No. 9.—A Study of Output in Silk Weaving during the Winter Months, by P. M. ELTON, M.Sc. 1920. (69 pages). [Price 2s. 6d. net, post free 2s. 8d.]

The report deals with the hourly, daily and weekly variations in production in two silk weaving mills, making plain and fancy goods respectively, by analysis of output data collected continuously for four months from 98 looms. The various factors affecting production are discussed, and it is shown that the curve of distribution of output throughout the day has a characteristic shape. A gradual increase in output occurs from December to March, coinciding roughly with the lessened use of artificial light, under which production appears to fall about 10 per cent. as compared with daylight. Suggestions are also made for increasing efficiency, in particular the keeping of certain records.]

No. 17.—An Analysis of the Individual Differences in the Output of Silk Weavers, by P. M. ELTON, M.Sc. 1922. (38 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[The report embodies the results of an investigation into output in silk-weaving, but these are applicable with little modification to any type of weaving.

Part I deals with the extent of the differences in individual performance, and shows that while the performance of any given weaver remains at about the same level for any given quality of cloth, there is no definite line of demarcation between good and bad weavers, the two classes merging into one another insensibly. Further, the large but consistent differences in loom efficiency manifested as between one weaver and another indicate how greatly production in power-loom silk weaving is dependent on the human factor.

Part II is concerned with the causes of the differences in individual performance. These have been investigated by means of time study, applied to ascertain how far and in what respect individual differences in method are related to efficiency in weaving. By means of a full classification of the various causes of loom stoppage and observation of the methods adopted in each case, some of these methods are known to be definitely good and others to be definitely bad, indicating the importance of adequate preliminary training in weaving. Actual specimens of the time analysis sheets containing the data for selected weavers are given and explained, and suggestions are made for its further use.

The report itself is confined to silk-weaving, but the methods described and conclusions drawn are applicable with little modification to power-loom weaving in any of the textile trades.]

No. 20.—A Study of Efficiency in Fine Linen Weaving, by H. C. WESTON, M.J.Inst.E. 1922. (iii and 28 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[The report embodies the results of a special investigation conducted into a process, which for successful manufacture a high atmospheric temperature and a high degree of humidity are required. The results indicate that up to a certain limit of wet-bulb temperature (73° F.) productive efficiency increases with the temperature, but that above that limit efficiency falls, notwithstanding the favourable physical effects of the atmospheric conditions, owing to the discomfort and fatigue of the weavers. The physiological view that working disability begins at a wet-bulb temperature of 70° to 75° thus receives confirmation.

The relation of illumination to efficiency is also discussed, and evidence is given showing that the use of artificial light reduces efficiency by about 11 per cent. of its normal daylight value.]

No. 21.—Atmospheric Conditions in Cotton Weaving, by S. WYATT, M.Sc. 1923. (x and 36 pages). [Price 2s. net, post free 2s. 2d.]

[The report is based on an extensive series of observations of the temperature and movement of the air, and of its cooling power as measured by the dry and wet kata-thermometer in eight humid weaving sheds. A comparison is drawn between winter and summer observations, and examples are given of the daily variations in temperature and cooling-power with explanations of the differences which occur.

Suggestions are made for increasing the cooling-power by increasing the air movement, and an account is given of a small-scale experiment carried out with this object.

Finally, the atmospheric conditions in humid weaving sheds are compared with those in other factories, and detailed instructions are given for using the kata-thermometer, the instrument with which the observations of cooling-power were made.

The preface contains a short account of the legislative and official action taken in regard to humidified factories in the United Kingdom.]

No. 23.—Variations in Efficiency in Cotton Weaving, by S. WYATT, M.Sc. 1923. (vii and 60 pages). [Price 3s. 0d. net, post free 3s. 2d.]

[This report is based principally on hourly output (pick-recorder) readings taken on about 600 looms over a period of one year, amounting in all to over one million. In these the high and uniform standard of efficiency generally maintained in cotton weaving is clearly indicated. The variations in efficiency over the year, week and day, are fully discussed, and the various factors in efficiency (distinguished as environmental, personal, and physical) analysed. Owing to the large volume of data involved, individual and chance variations are eliminated in the final results, but the general tendencies that emerge may be accepted as real. It is shown, for instance, that at temperatures over 75°F. productive efficiency tends to fall owing to fatigue on the part of the workers, and also that during periods of artificial lighting output may be reduced by 5 per cent.]

Boot and Shoe Industry.

No. 10.—Preliminary Notes on the Boot and Shoe Industry, by J. LOVEDAY, B.A., and S. H. MUNRO. 1920. (32 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[The report embodies some miscellaneous points of interest arising during the initial stages of an investigation into the boot and shoe industry. It contains an historical introduction and an illustrated description of the principal processes, followed by two short sections bearing on fatigue and efficiency. The first of these deals with variations in output during the day for certain operations, and in it two inferences are drawn, first, that output on Saturday is always relatively low, and secondly, that the rate of production of a skilled worker is more regular and tends to fall later in the week than that of a worker whose skill is less or who is ill-suited to his work. The final section of the report is devoted to an account of an experiment with regular rest-pauses in a certain pressroom, by means of which the average output from six presses was increased by 44 per cent. without the addition of new machines and with a reduction in the working hours of the individual operative.]

No. 11.—Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories, by W. D. HAMBLY, B.Sc., and T. BEDFORD. (70 pages, with plates). 1921. [Price 3s. net, post free 3s. 2d.]

[This report is concerned with the practical use of the kata-thermometer as an indicator of atmospheric conditions from a physiological aspect, and is based upon observations taken in 35 boot and shoe factories under varying conditions, and also in an aircraft doping room. It is a preliminary step towards the investigation of the relation of atmospheric conditions to fatigue and efficiency.

The report begins by enumerating the atmospheric conditions which are physiologically desirable (as enunciated by Dr. Leonard Hill). After a description of the kata-thermometer and its use, the observations in the various factories are discussed, and a comparison drawn between single storey and multi-storey buildings in regard to atmospheric conditions. The conclusions reached are summarised in the report, which is illustrated by detailed tables. In an appendix the uses of frequency curves are explained.]

Pottery Industry.

No. 18.—Two Investigations in Potters' Shops, by H. M. VERNON, M.D. (assisted by T. BEDFORD). 1922. (74 pages, with plates). [Price 2s. 6d. net, post free 2s. 8d.]

[Part I embodies the results of an investigation into the atmospheric conditions of potters' shops, in regard both to temperature and to cooling-power as measured by the kata-thermometer. The effects of the different types of stove are discussed, and the conditions in potters' shops are compared with those found in other types of factory.

Part II deals with the effect on atmospheric conditions of different types of stove, and in particular with extent to which hot air is admitted in the work-rooms. It also contains the results of experiments on the relative importance of temperature and air velocity in the drying of moist ware, and suggestions are made for improvement of the conditions.]

Laundry Industry.

No. 22.—Some Studies in the Laundry Trade, by MAY SMITH, M.A. (v and 57 pages, with plates). 1922. [Price 2s. 6d. net, post free 2s. 8d.]

[This report embodies the results of an extensive survey conducted into the conditions of work in the laundry trade, and is based partly on actual observation of workers performing certain operations and partly on the application to workers of a psychological test. The atmospheric conditions of laundries explored by means of the kata-thermometer are also discussed, and a comparison is drawn between laundries and factories in other industries. Finally, suggestions are made, showing how certain improvements can be effected. Detailed instructions for using the kata-thermometer are appended.]

Glass Industry.

No. 24.—A Comparison of different Shift Systems in the Glass Trade, by E. FARMER, M.A. 1923. (iv and 24 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[The report embodies the results of an investigation promoted by the Industrial Fatigue Research Board and the Glass Research Association.

The effects of the different shift systems (chiefly ten-hour and eight-hour) adopted in the industry are compared, and the conclusions reached confirm those obtained in other industries involving the same type of work, in showing that a reduction in the length of shift brings about an increase in hourly output, though this increase is not sufficient to bring the output of the shorter shift to the level of the longer shift. The total output per day of twenty-four hours is, however, greater on the shorter shift system.

Other points dealt with in the report include the comparative efficiency of the day and night shifts, the seasonal variation in output, the effects on output of temperature and ventilation, practice, and long stoppages.]

Light Repetition Work.

No. 25.—Two Studies on Rest-Pauses in Industry, by H. M. VERNON, M.D., T. BEDFORD, and S. WYATT, M.Sc. 1924. (iv and 34 pages.) [Price 1s. 6d. net, post free 1s. 7½d.]

[The report deals with the effects of breaking up the spells of work in occupations involving light repetitive work by means of short rest-pauses of definite duration and inserted at definite intervals in the spell.

It is divided into two parts. The first part is based on the results of observations in certain factories in which a system of rest-pauses is adopted, and the effect of these is estimated by comparing the output before and after the operation of the system. The second part contains the results of some laboratory experiments, in which different types of light industrial work were reproduced and the effect of interpolated rest-pauses determined.

The two methods confirm one another in showing that the introduction of systematic rest-pauses was almost always followed by a small but genuine improvement in output, and there seems to be justification for stating that in light repetitive work the judicious introduction of rest-pauses may not only tend to reduce monotony and so increase the contentment of the workers, but may also bring about an improvement in output amounting to 5 to 10 per cent., in spite of the diminution in working-time.

Much work still remains to be done on this subject, and the present report is published at this stage in order that employers may consider the desirability of experiment.]

No. 26.—On the Extent and Effects of Variety in Repetitive Work, by H. M. VERNON, M.D., and S. WYATT, M.Sc. 1924. (iv and 38 pages). [Price 1s. 6d. net, post free 1s. 7½d.]

[The report is based on an investigation on different types of uniform repetitive work, and is divided into two parts.

In the first part the extent to which repetitive work, when carried out under practical conditions, is really continuous is discussed, and examples of observations on different processes are quoted showing how far an element of variety enters into work of this type.

In the second part the effects on output of experimental changes in the type of work carried out are described. The results, though admittedly tentative, suggest that there is an optimum condition between complete uniformity of work and frequent changes at which maximum output is maintained. Some confirmation on this point is received from some laboratory experiments, which showed that spells of work in which changes of activity were periodically introduced gave a much higher output and less spoiled work than spells in which the same activity was maintained throughout.]

IN THE PRESS.

No. 30.—An Experimental Investigation into Repetitive Work, by ISABEL BURNETT.

No. 31.—Performance Tests of Intelligence, by FRANCES GAW.

No. 32.—Rest-pauses in Industrial Occupations, by S. WYATT (assisted by J. A. FRASER).

No. 33.—Studies in Vocational Guidance.

OTHER PUBLICATIONS.

BEDFORD, T. (1922): The Ideal Work Curve.—*J. Ind. Hyg.*, **4,** 6.

CATHCART, E. P., BEDALE, E. M., and MCCALLUM, G. (1923): Studies in Muscle Activity.—I. The Static Effect.—*J. Physiol.*, **57,** 3 & 4.

CRIPPS, L. D., GREENWOOD, M., and NEWBOLD, E. M. (1923): A Biometric Study of the Inter-relations of Vital Capacity, Stature Stem Length and Weight in a Sample of Healthy Male Adults.—*Biometrika*, **14,** 3 & 4.

FARMER, E. (1922): Time and Motion Study.—*J. Ind. Hyg.*, **4,** 5.

FARMER, E. (1923): Interpretation and Plotting of Output Curves.—*Brit. J. Psych.*, **13,** 3.

FARMER, E., and CHAMBERS, E. G. (1925): Concerning the Use of the Psycho-galvanic Reflex in Psychological Experiments.—*Brit. J. Psych.*, **15,** 3.

FRASER, J. A. (1924): The Vocational Selection and Training of Operatives for the Weaving Industry.—*J. Nat. Inst. Ind. Psych.*, **2,** 2.

GAW, F. (1923): The Use of Performance Tests and Mechanical Tests in Vocational Guidance.—*J. Nat. Inst. Ind. Psych.*, **1,** 8.

GREENWOOD, M., and NEWBOLD, E. M. (1923): On the Estimation of Metabolism from Determinations of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism.—*J. Hyg.*, **21,** 4.

HAMBLY, W. D., and MCSWINEY, B.A. (1922): The U-tube Manometer Test with relation to Muscular Exercise.—*Proc. Physiol. Soc.*, Oct. 21, 1922.

HEWITT, E. M., and BEDALE, E. M. (1923): A Study of the Comparative Physiological Costs of Different Methods of Weight carrying by Women.—*Ann. Rep. of the Chief Inspector of Factories for 1922.*

HILL, A. V., LONG, C. N. H., and LUPTON, H. (1924): Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Proc. Roy. Soc.*, B. **96,** 438; **97,** 84; **97,** 155.

HILL, A. V., and LUPTON, H. (1923): Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med.*, **16,** 62.

HILL, L., VERNON, H. M., and HARGOOD-ASH, D. (1922): The Kata-Thermometer as a Measure of Ventilation.—*Proc. Roy. Soc.*, B. **93,** 198.

LUPTON, H. (1922): Relation between External Work and Time Occupied in a Single Muscular Contraction.—*J. Physiol.*, **57,** 1 & 2.

LUPTON, H. (1923): Exercise and Oxygen.—*Med. School Gaz.*, **2,** 3.

LUPTON, H. (1923): An Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57,** 6.

MUSCIO, B. (1920) : Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10,** 4.

MUSCIO, B. (1921) : Is a Fatigue Test Possible ?—*Brit. J. Psych.*, **12,** 1.

MUSCIO, B. (1921) : Feeling Tone in Industry.—*Brit. J. Psych.*, **12,** 2.

MUSCIO, B. (1922) : Motor Capacity with special reference to Vocational Guidance.—*Brit. J. Psych.*, **13,** 2.

MUSCIO, B., and SOWTON, S. M. (1923) : Vocational Tests and Typewriting. —*Brit. J. Psych.*, **13,** 4.

NEWBOLD, E. M. (1923) : Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika*, **15,** 3 & 4.

PEMBREY, M. S., & OTHERS (1922) : Tests for Physical Fitness.—Part I.— *Guy's Hospital Reports*, Oct., 1921.—Part II.— *Ibid.*, Oct., 1922.

RUSHER, E. A. (1922) : The Statistics of Industrial Morbidity in Great Britain.— *J. Roy. Stat. Soc.*, **85,** 1.

SMITH, MAY (1923) : Practical Problems of Industrial Life.— *Ind. Welfare*, **5,** 58.

SMITH, MAY (1923) : The Laundry Trade.—*Laundry Record*, **33,** 388.

SMITH, MAY (1924) : Ventilation in Laundries.—*J. Ind. Hyg.*, **7,** 4.

STURT, M. (1922) : A comparison of Speed with Accuracy in the Learning Process.—*Brit. J. Psych.*, **12,** 3.

VERNON, H. M. (1921) : The Influence of Atmospheric Conditions on Industrial Efficiency.— *J. State Med.*, **29,** 353.

VERNON, H. M. (1921) : The Influence of Fatigue on Health and Longevity. —*J. Ind. Hyg.*, **3,** 3.

VERNON, H. M. (1922) : Atmospheric Conditions in Industry.— *J. Ind. Hyg.*, **4,** 8.

VERNON, H. M. (1922) : The Influence of Rest Pauses and Changes of Posture on the Capacity for Muscular Work.— *J. Physiol.*, **56,** 6.

VERNON, H. M. (1922) : Recent Investigation on Atmospheric Conditions in Industry.— *J. Ind. Hyg.*, **4,** 8.

VERNON, H. M. (1923) : A Note on the Causes of Output Limitation.— *J. Nat. Inst. Ind. Psych.*, **1,** 5.

VERNON, H. M. (1923) : Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.—*Trans. Ceramic Soc.*, 22, p. 70.

VERNON, H. M. (1923) : The Causation of Industrial Accidents.— *J. Ind. Hyg.*, **5,** 1.

VERNON, H. M. and BEDFORD, T. (1924) ; The Influence of Short Time on Speed of Production.—*J. Nat. Inst. Ind. Psych.*, **2,** 4.

VERNON, H. M. and BEDFORD, T. (1924) : An Investigation of the Atmospheric Conditions in Coal Mines by means of the Kata-thermometer.—*J. Ind. Hyg.*, **6,** 4.

VERNON, H. M. (1925) : The Kata-thermometer as an Indicator of Radiant Heat.—*J. Nat. Inst. Ind. Psych.*, **2,** 5.

WALLER, A. D., and DE DECKER, G. (1921) : The Physiological Cost of Muscular Work measured by the exhalation of Carbon dioxide.— *Brit. M. J.*, May 7, 1921.

WESTON, H. C. (1923) : Some Results of an Investigation into the Efficiency of Linen Weavers.—*J. Ind. Hyg.*, **5,** 2.

WILSON, D. R. (1921) : Some Effects of Environment on Efficiency and Safety.— *J. Roy. San. Inst.*, **42,** 3.

WILSON, D. R. (1921) : The Work of the Industrial Fatigue Research Board, and its applications to Industry.— *J. Roy. Soc. Arts*, **70,** 3660.

WILSON, D. R. (1923): On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.*, **86**, 4.

WILSON, D. R. (1923): International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office Studies and Reports, Sec. F., No.* 9.

WILSON, D. R. (1924): Some Observations on Industrial Lighting.—*J. Ind. Hyg.*, **5**, 10.

WILSON, D. R. (1924): Man in Relation to Production.—*First World-Power Conference*, **412**.

WYATT, S., and WESTON, H. C. (1920): A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.*, **10**, 4.

Printed by H.M.S.O. Press, Harrow.

NOTE.—A list of the Publications of the Industrial Fatigue Research Board appears on page 64 of this Report. The Reports can be purchased directly from

H.M. STATIONERY OFFICE at the following addresses:

ADASTRAL HOUSE, KINGSWAY, LONDON, W.C.2, and
28, ABINGDON STREET, LONDON, S.W.1;
YORK STREET, MANCHESTER;
1, ST. ANDREW'S CRESCENT, CARDIFF; or
120, GEORGE STREET, EDINBURGH;
or through any Bookseller.

The offices of the Board are unable to supply them directly.

N.B.—Applications by post to the above addresses should quote the description in full of the publications wanted, and should be accompanied by the price as indicated in the list.