GT. BRIT. INDUSTRIAL FATIGUE RESEARCH BOARD

INCIDENCE OF INDUSTRIAL ACCIDENTS UPON INDIVIDUALS

MEDICAL RESEARCH COMMITTEE

INDUSTRIAL FATIGUE RESEARCH BOARD

(Later the Industrial Health Research Board)

REPORT No. 4

THE INCIDENCE OF INDUSTRIAL ACCIDENTS UPON INDIVIDUALS

with Special Reference to Multiple Accidents

By MAJOR GREENWOOD and HILDA M. WOODS

LONDON: HER MAJESTY'S STATIONERY OFFICE

1919

PRICE TWO SHILLINGS NET

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PREFATORY NOTE.

In December, 1917, the Secretary of State for Home Affairs invited the Department of Scientific and Industrial Research to appoint a Committee to investigate the subject of Industrial Fatigue on comprehensive and systematic lines, and a similar proposal was made by the Medical Research Committee.

A Research Board was accordingly appointed by the Department of Scientific and Industrial Research and the Medical Research Committee jointly, with the following membership:—

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Bertram Wilson (*Assessor* representing the Ministry of Labour).

D. R. Wilson (H.M. Inspector of Factories)—*Secretary.*

Its terms of reference are:—" To consider and investigate the relations of the hours of labour and of other conditions of employment, including methods of work, to the production of fatigue, having regard both to industrial efficiency and to the preservation of health among the workers."

The duty of the Board is to initiate, organise and promote by research grants or otherwise, investigations in different industries with a view to finding the most favourable hours of labour, spells of work, rest pauses, and other conditions applicable to the various processes according to the nature of the work and its demands on the worker. Reports embodying the results of these investigations will be issued from time to time.

The question how far and in what circumstances the occurrence of industrial accidents may be taken as indicative of fatigue, is one of obvious importance in connection with the work of the Board. It has to some extent been investigated in previous researches,* but has never been fully explored. As a preliminary to any such exploration, it is desirable to ascertain whether accidents are distributed equally among the workers in the dangerous processes, or are more or less limited to particular individuals, and if the latter is the case, the explanation of the unequal distribution. The present Report, which is based on the statistical investigation of certain accident records in possession of the Ministry of Munitions, discusses this point. It affords strong grounds for thinking that the bulk of the accidents occur to a limited number of individuals who have a special susceptibility to accidents, and suggests that the explanation of this susceptibility is to be found in the personality of the individual

August, 1919.

15, Great George Street,
S.W.1.

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* *See, e.g.*, An investigation of the Factors concerned in the Causation of Industrial Accidents, by H. M. Vernon, M.D. (Memorandum No. 21 of the Health of Munition Workers' Committee (Cd. 9046). (Price 6*d*. net.)

A REPORT ON THE INCIDENCE OF INDUSTRIAL ACCIDENTS UPON INDIVIDUALS WITH SPECIAL REFERENCE TO MULTIPLE ACCIDENTS.

By MAJOR GREENWOOD, *Lister Institute of Preventive Medicine and Research Sub-Section, Ministry of Munitions (Welfare and Health Section), and* HILDA M. WOODS, *Ministry of Munitions.*

CONTENTS.

I.—INTRODUCTION.

When a number of persons engaged upon a specific task are observed over a period of some weeks or months, they are often found to have sustained a certain number of casualties; if such casualties are so trivial as to permit the victim to continue work, it may also be observed that the same person is injured more than once, so that the statistics of the whole period provide a certain number of persons who have passed through unscathed, some who have been injured once, others who have been injured twice, and so on.

A frequency distribution of this kind arises under various conditions and the proportions of the whole population found in its different subdivisions will be regulated by the group of causes which determine the happening of the event in question. If for instance we distributed amongst a set of families, each containing the same number of members, some source of infection (perhaps a person suffering from influenza might go to reside in each family), then we should ultimately have statistics of multiple cases of influenza, some families having no cases (other than that of the intruder), some having one, two, and so forth. But even without the supposed importation, and if sickening with influenza were as much a matter of chance as the drawing of an ace of spades from a well shuffled pack of cards, which we should do once on the average in every 52 trials, we should still expect to find that the statistics give instances of families with more than one case of influenza.

To take another illustration, let us suppose that 100 equally capacious and equally accessible pigeon holes are bombarded with 20 balls, none of which can fall clear of the pigeon holes altogether, then the chance of any one ball lodging in any particular pigeon hole is one in a hundred, and at the end of the bombardment the distribution of pigeon holes with 0, 1, 2, etc. balls in each is given by the 21 successive terms of:

$$100\left(\frac{99}{100}+\frac{1}{100}\right)^{20}$$

But the pigeon holes might not be of equal size. If some were very much larger than others, the former would receive a greater share of the balls and the distribution would be very different from that just given. Similarly if the pigeon holes changed size after the bombardment had commenced, the distribution would be affected. The extreme limits of the two modifications would be reached if either (*a*) all the pigeon holes save one were covered in, when the final distribution would necessarily be 1 pigeon hole with 20 balls and 99 with none, or (*b*) if directly a ball entered a pigeon hole a lid fell—as in the trap nest of a poultry fancier—which would lead to an ultimate distribution of 80 pigeon holes with no balls and 20 with one each.

These examples, although their analogy to the subject we are engaged upon is but imperfect, start a train of thought. Knowing the form of the ultimate distribution of pigeon holes with various numbers of balls, it is evidently practicable to form a judgment as to the nature of the causes which have operated in the distribution, since these will completely determine the result. We say advisedly "*form a judgment as to*" and not "*prove what was*" because an inverse problem of this kind presents certain difficulties which we have no space to discuss. Following up this trail might it not similarly be possible, from a consideration of statistics of multiple accidents, to reach a judgment as to factors producing these?

To make our point clear, let us discuss the genesis of accidents more at large We have not, however, to consider any general influences common to the whole number of persons studied. Such influences will not affect the distribution of accidents as between individuals, but will modify the general scale; they are of course of immense importance because they may determine the total numbers of accidents sustained, but need another method of investigation and have in fact been studied by other workers. We are only dealing with the differentiation of individuals.

The simplest hypothesis is that there is *no* differentiation, that industrial accidents are really accidents in the strictest sense, just as it is an accident if one draws the ace of spades from the well-shuffled pack, an accident if a particular pigeon hole receives a ball at any particular throw and so on. In that event, the statistics of multiple accidents would conform to the type of a pure chance distribution of which the first arrangement of pigeon holes imagined above is one illustration.

The most obvious modification of the pure chance scheme is to suppose that the workers did all start equal, but that an accident having happened to any individual that individual's chance of sustaining a second accident became different from what it was before. Such a train of events is common enough in human life. A person may acquire some disease by the merest accident, but passing through the attack will profoundly modify his chance of acquiring it again when the original conditions are, in all other respects, reproduced; he may be practically immune or conversely he may be much more sensitive to infection. The analogous schema in our sets of pigeon holes is that of the trap nests, although the analogy is imperfect because in that case not only is the future chance of the particular pigeon hole modified, which is correct, but, by the conditions that all 20 balls must ultimately rest somewhere in the 100 pigeon holes (introduced for simplicity) the chance of the empty pigeon holes is also modified, which is wrong, for the happening of an accident to one person should not generally affect anyone else's chance.

Thirdly we might suppose that all the workers did not start equal, but that some were more liable to suffer casualties than others; suppose there were only two classes, clumsy and careful people, then the analogy would be 100 pigeon holes, 50 having an opening of 1 square foot and 50 having an opening of 2 square feet and we should get another special distribution of multiple accidents.

These three hypotheses correspond to three distinct policies of organisation.

If industrial accidents were found to be allocated upon a pure chance schema, the diminution of their number would be effected by a change of scale through administrative reforms inspired by researches into general conditions, but not into the individual physiology or psychology of the worker. Were the second mentioned hypothesis in better accord with the facts, there would be need for consideration whether the enhanced liability to accident after a first casualty (supposing the bias were in that direction) might not be reduced, perhaps by a compulsory period of rest, possibly by a short interval of different work. If, on the other hand, the third possibility materialised, it would follow that both initial selection of recruits and also a rapid elimination of those sustaining multiple accidents should have a great effect in reducing the casualty rate of the factory.

It seemed therefore possible that an investigation of the statistics of multiple accidents might yield results of some practical importance and we felt justified in making a preliminary survey of the field; a full discussion of the various mathematical questions suggested by the data will be published in a memoir by Mr. G. Udny Yule and one of us at a later date.

We desire to express our obligations to various colleagues in the Ministry of Munitions, particularly Miss Broughton and Mrs. Osborne, who have provided us with statistical material.

II.—STATISTICAL METHODS.

When it has been desired to ascertain whether the distribution of multiple events actually observed in any case were such as might arise upon the hypothesis of a pure chance determination, the schema of pigeon holes into which balls are tossed has been adopted by the best modern exponents of applied mathematical probability.

This schema was used by, for instance, Professor Karl Pearson in a study of the occurrence of multiple cases of cancer in houses and in connection with the similar problem of recurrent enteric fever in houses. When the number of pigeon holes is very large but the ratio of balls to pigeon holes finite, the formula admits of rapid computation by means of an approximation (*see* Appendix).

The *a priori* objections to this schema as a proper representation of what occurs in a chance distribution of accidents are formidable. In effect, the assumption is made that n accidents *must* happen to the N persons, all that we have to do being to distribute them; but it might properly be retorted that a true analogy is that of a platoon of soldiers exposed to fire of whom a certain number are struck once, some twice and so on. Now suppose the number of bullets discharged (irrespective of whether they find billets or not) is M and the number of wounds inflicted (again irrespective of whether they are inflicted upon different bodies) n; then the chance of being struck being p and of being missed $1-p=q$, we can determine values of the unknown chance from the mean and second moment of the distribution; we take the chance of being wounded as not given *a priori*.

In practice, however, these two fundamentally different methods do not really lead to widely divergent final distributions. This is illustrated by the following examples. In A, 400 accidents are distributed amongst 10,000 persons by the pigeon hole schema. In B it is assumed that the same number of persons were exposed to risk of accident during 4 units of time, the chance of having an accident in each unit being one in a hundred and the unit so small that no two successive accidents could occur within it.

We have:—

Accidents per Person.	*Frequency by A.*	*Frequency by B*
0	9608	9606
1	384	388
2	8	6
3	0	0

The reason of this accord is that in each case the form of distribution approximates to that obtained by the series mentioned in the first section of the appendix, viz.:—

$$e^{-\lambda}\left(1+\lambda+\frac{\lambda^2}{2!}+\frac{\lambda^3}{3!}\ \cdots\right)$$

where λ is the number of accidents divided by the number of persons. Consequently whenever the conditions are such that the chance of sustaining an accident must be deemed small (and these conditions are fulfilled in the majority of cases), the unmodified pigeon hole schema is probably a quite adequate test of the likelihood that the distribution is one of pure chance in origin, and this is the test we have uniformly applied.

The second hypothesis to be tested, viz., that in a population initially all equally liable and exposed to risk, those who experience first accidents are by virtue of that experience rendered more or less liable to have another accident, is *not* satisfactorily imitated by the modification of the pigeon hole schema which we indicate in the Appendix.

There is no algebraical difficulty in devising a much more appropriate schema, one not suffering from the obvious defect that increasing the size of certain pigeon holes diminishes the size of the remainder, the total space within all the pigeon holes together being kept constant. The requisite algebraical formula has been worked out and will be given in the paper by Yule and one of us to which reference has been made. But it was found on trial that this more correct formula produced a distribution very similar to that reached with the modification of the pigeon hole schema just mentioned, while actual fitting to data was extremely laborious and not in general practicable in terms of the lower moment coefficients. Hence, although fully alive to the imperfections of the modified pigeon hole formula, we have utilised it as some test of the physiological theory.*

The third hypothesis, viz., that of *ab initio* differentiation, is we think quite sufficiently tested with the aid of the third formula in the Appendix. We do not of course mean that the assumption involved in equation (5) of that Appendix is necessarily correct, but merely that it provides the kind of distribution which we should naturally anticipate and has the advantage of leading to a series the constants of which can be deduced from the first two moments of the statistics.

These three methods then, that of a Simple Chance Distribution (denominated in our tables by the letters C.D.), that of a Biassed Distribution (entered as B.D.), and that of a Distribution of Unequal Liabilities (indicated by U.D.), have been used throughout. A criterion of agreement between the deductions from the formulæ and the statistical facts has been obtained by using Professor Pearson's Goodness of Fit Test as modified by him in the under-cited paper.†

We shall first set out the tabular results yielded by data recording the numbers exposed to risk (we of course satisfied ourselves that the material conditions of exposure to risk were really approximately constant in each set of data), and the distribution of multiple accidents. We shall then examine some statistics providing more detailed information (Tables I.-IX.).

As will be seen from the headings of the tables, the sources of the data are various; sometimes we had merely a record of the total numbers employed in a particular shop over a given period, on other occasions we were furnished with the records of a number of women chosen at random, *e.g.*, by the fact of their names occurring on particular pages, while in one set of data the method of selection was to take a random sample of women who had, and of women who did not have, an accident during a particular month. It must be noted that the last-mentioned method, although indifferent if accidents are truly random, is not indifferent if the true cause be varying personal liability; on that hypothesis such selection is differential.

A glance at the tables is enough to show that the C.D. hypothesis is altogether inadequate, while in a majority of cases

* A number of trials led to the conclusion that formula (2) of the Appendix gives a distribution hardly distinguishable from the true value, provided s does not exceed about $2 \cdot 3$ and N is not greater than 1000. In only one of the instances here examined (that of Table IV.) did s exceed $2 \cdot 3$; hence the approximation is probably sufficient.

† Biometrika, IX. 1913, p. 28. See footnote to Table I.A.

the other two hypotheses provide good fits; but on a general review of the data (Table X.) it is apparent that the U.D. method is decidedly superior. In five cases the B.D. distribution fails, the U.D. only twice (it is noteworthy that two sets of data which neither hypothesis fits are mere enumerations of totals employed and therefore the guarantee of equal exposure to risk is much slighter than in other cases). The superiority of the method of Unequal Liability is not a mere consequence of using a formula with one more constant; two moments are involved in each calculation; hence it appears just to infer that the hypothesis of the deviation from simple chance being dependent upon unequal initial liability to accident is sustained. We now proceed to examine the point more strictly.

It is evident that if the C.D. principle held, the previous record of any individual would be without influence upon his or her subsequent experience, just as if in one particular set of tosses a certain coin fell heads five times running, that coin would be neither more nor less likely to fall heads five times in a subsequent experience.

But if some one coin were biassed in favour of falling heads, then its records in successive experiments would naturally be inter-related. Having in some of our data records of previous experience, we can easily determine which case responds to the reality, and in Tables XI.-XIII. are set out the records of women who in a particular month did or did not have accidents. It will be seen that almost invariably the balance of accidents is heavily against those women who fell victims in the month taken as a criterion of classification.

A yet more striking result is shown by other data which we owe to the zeal of some welfare supervisors in a great National Factory. These data were compiled with exceptional care and relate to random samples of women whose accidents, output and lost time over a trial of three months were carefully recorded, and whose accident experience in the previous three months was likewise available. We first went through these data and rejected all women who had not been in employment at the factory at least eight months when the record was made and we likewise rejected those who had been absent from work 14 days or more during the trial period. There remained 22 in one and 21 in another shop (the samples related in each case to women employed throughout the trial period upon one and the same lathe operation). We then correlated the individual's accidents in the two successive periods of three months. Tables XIV. and XV. exhibit the results from which it appears that in both processes the correlation* is substantial and especially note-

* [The coefficient of correlation is a measure of the tendency of two variable magnitudes to increase or decrease together, or, alternatively, of the tendency of one to increase as the other decreases. The coefficient cannot exceed unity in absolute magnitude: a value of +1 would indicate that the variables increased or decreased strictly *pari passu*. Similarly a value of −1 would mean that the increase of one involved a strictly proportional decrease of the other.]

worthy in the sample of heavy lathe operatives, who were performing what is considered to be a strenuous task. Tables XVI. XVII. covering all the records tell the same story.

Since there is considerable correlation between the records of successive periods, there can be little doubt that the C.D. hypothesis is inappropriate. To discriminate between the two other suppositions a further investigation is necessary. Upon either hypothesis we should expect to find correlation, but, were the B.D. hypothesis correct, the observed correlation would be increased by eliminating from the record individuals who sustained no accidents in the first period because, *ex hypothesi*, these persons are neither more nor less likely to have accidents in the second period than they were before; hence their presence amounts to a dilution of correlated pairs with uncorrelated pairs. On the other hand by the U.D. hypothesis there is correlation between immunity in one period and immunity in the following period. Accordingly if we remove the pairs the first members of which are zeros, the correlation should increase if the B.D. hypothesis is correct, but not otherwise. Table XVII.A, shows that in every instance the correlation is reduced, although the difference is hardly significant. The conclusion, then, is that the supposition of unequal initial liabilities better explains the facts, as was suggested by the previous investigation.

These results indicate that varying individual susceptibility to "accident" is an extremely important factor in determining the distribution; so important that given the experience of one period it might be practicable to foretell with reasonable accuracy the average allotment of accidents amongst the individuals in a subsequent period (Table XVIII.). This result is in itself of considerable interest, because it shows that by weeding out susceptibles the accident rate would necessarily decline; but before much practical value attaches to it we must be a little clearer as to what one ought to mean by this phrase individual susceptibility.

The naive interpretation is of course that of carefulness or carelessness; as one says, there are people whose fingers are all thumbs and there are others who are neat fingered; or again some people are scatter-witted and others circumspect; do our results amount to more than an arithmetical verification of this? Perhaps not, but there are other possibilities. Industrial accidents are usually held to be a function of output, and also a function of fatigue; the faster one works the greater the number of accidents, and the more weary one is when working at the same rate the greater the risk of misadventure.

We naturally ignore in this investigation any effect of *general* increase of output or of *general* fatigue due to conditions affecting all, but individual variations do concern us. Then again, our records of accidents are of *reported* accidents and, with few exceptions, the accidents are trivial, small cuts, slight burns, foreign bodies in the eye, rarely involving either absence from work or recourse to a surgeon. But the nervous or ultra careful woman may, for various reasons, report accidents which the average woman would disregard altogether. Consequently we have sheltering under the term individual susceptibility, a motley host of motives or factors which will be very difficult indeed to separate and measure. Two variables, however, we can attempt to deal with, viz., output and general sickness.

Tables XIX. and XX* relate to the data used in Table VIII., and the records of broken time were not so accurate as we could wish; they show no measurable difference of output between the women who had and those who did not have accidents.

Tables XXI.-XXIV. relate to the women figuring in Tables XIV.-XVII., and here the records of lost time were much more satisfactory. Output has been reduced to terms of hours actually worked. It will be noticed that the heavy lathe operatives and the profilers vary in opposite directions; but in view of the absolute smallness of the divergences, and paying attention to the error of sampling, we do not think any stress can be put upon the result; so far as our data go the differentiation of those who do, from those who do not, have accidents cannot be shown to be related to a similar differentiation in the matter of output. Those who sustain many accidents are on the average neither less nor more productive workers than their fellows.

In Tables XXV. and XXVI. time lost by sickness is brought into relation with the accident record. Here there is, perhaps, some indication of a difference, sickness lost time being negatively correlated with accidents. But, as Professor Loveday pointed out, the allocation of lost time to different causes is, unless medical certificates of a trustworthy character are available, extremely unreliable, so that the relation may mean little more than a tendency to credit some sickness or lost time to accidents among women who have had accidents, the real attribution being uncertain.

Accidents have also been correlated with age (Tables XXVII. and XXVIII.), but the results again are of no practical importance.

In Tables XXIX. and XXX. the accident data are tabulated by civil state; no significant difference can be detected.

It is of course evident that the investigations detailed in the last paragraphs will need to be repeated upon much larger numbers of observations before the negative conclusions suggested therein can be taken to be demonstrated. But, so far as our present knowledge goes, it seems that the genesis of multiple accidents under uniform external conditions is an affair of personality and not determined by any obvious extrinsic factor, such as greater or less speed of work. We cannot say that the victims are less healthy persons than those who escape, or that they are better workers—so far as our data go there is no reason to think that they are specially productive workers. If this conclusion be confirmed by a wider investigation the practical corollary is

* The outputs shown in the different tables are not comparable directly, as the operations and material were not the same.

obvious. The "susceptible workers" should be transferred so far as practicable from processes involving any special risk of accident to occupations not exposing to any such risk.

It is perfectly true that, in the particular occupations we have studied, the accidents are rarely serious, and, according to our results, do not lead to a deterioration of either general health or output. This inquiry was not undertaken for the sake of those occupations alone, but in the hope of throwing light upon the general problem. Naturally we chose branches of a trade in which accidents were usually trivial, as otherwise we should have had grave difficulties in securing approximate equality of exposure to risk in different classes. The point is that with such material, we can determine whether accidents are randomly distributed like the fall of dice, and we have seen how the distribution diverges from that type.

The law of a *distribution* will not in general be affected by the consequences attaching to the results. The number of sixes thrown with a pair of true dice in a hundred trials will not be affected by the height of the stakes. Hence if we are warranted in referring the distributions here discussed to the factor of individual susceptibility we can have no hesitation in thinking that the same principle may apply to the genesis of accidents the results of which whether to the individual or to the plant may be grave. We should indeed expect that the *gross number* of accidents would be reduced, but their proportional distribution, as between individuals, might well remain the same. The consequences attaching to an accident will in fact change the absolute but not the relative scale, precisely as would alterations of any other factor (such as varying the temperature) affecting all the employees.

There are some industries—branches of the explosive supply trades for instance—in which accidents may lead to frightful disaster; nine times out of ten, perhaps 99 times out of a hundred, a trivial cut or scratch is the sole consequence; the tenth or the hundredth time the consequence is appalling. In our view, the results here described point a moral. Trivial accidents are indicators of unsafe people whom the record of the ambulance room can be employed to discover.

What numerical criterion of special susceptibility should be adopted, is not an easy question to answer. A rough rule would be to reckon within this category all workers who during an accounting period, say, of a month, are shown by their records to have sustained more than twice the number of accidents per head of the average over all operatives in the particular department. It is to be noted that the criterion should refer not to the severity but to the frequency of the accidents. From the present point of view a worker who has had three trivial accidents is a more dangerous person than one who has had a single bad wound.

In conclusion we have to express our gratitude both to Miss Broughton, Head Welfare Officer, and to the various Welfare Supervisors who have kindly provided us with numerical data.

III.—TABLES.

TABLE I.A.*—750 Women working on 60-lb. Shrapnel.

Accidents.	No. of Persons.	C.D.	B.D.	U.D
0	398	422	411	429
1	294	242	258	233
2	43	70	67	70
3	10	14	12	15
4	3	2	2	3
5	2	·23	·01	·4
Total ...	750	750	750 (P=002)	750 (P=0)

TABLE I.B.—580 Women working on 6-in. H.E. Shells.

Accidents.	No. of Persons.	C.D.	B.D.	U.D.
0	353	359	366	364
1	191	172	161	165
2	27	41	44	42
3	5	7	8	8
4	3	1	1	1
5	0	·1	·1	·2
6	1	·01	·01	·03
Total ...	580	580	580 (P=001)	580 (P=002)

TABLE II.—Women working on 6-in. H.E. Shell under same conditions in Shops A. & B. (Period February 13th, 1918–March 20th, 1918.)

Accidents.	Number having Accidents.	C.D.	B.D.	U.D.
Shop A.				
0	447	406	452	442
1	132	189	117	140
2	42	45	56	45
3	21	7	18	14
4	3	1	4	5
5	2	·1	1	2
Total ...	648	648·1	648 (P=·13)	648 (P=·39)

* The meaning of the quantity P. given in the first 10 tables is this : When a hypothesis requires the numbers of observations falling within a series of classes to be a_1, a_2, a_3. etc., and one actually finds b_1, b_2, b_3, etc. observations in these classes, the probability of the discrepancies having arisen by "chance" depends upon the value of the sum of such quantities as :—$\frac{(b_1 - a_1)^2}{a_1}$, and is denoted by the letter P. For instance. in Table II., Shop A, P = ·13 for the B.D. distribution means that were the hypothesis valid, then in every 100 trials we should get no better agreement than actually observed here 13 times. But for the U.D. hypothesis, the chance is better, viz., 39 in 100.

TABLE II.—*cont.*

Accidents.	Number having Accidents.	C.D.	B.D.	U.D.
Shop B.				
0	397	379	403	398
1	133	163	125	136
2	47	36	44	38
3	5	5	10	10
4	1	1	2	2
5	—	·1	·3	·6
6	—	—	—	—
7	1	—	—	—
Total ...	584	584·1	584·3 (P=·30)	584·6 (P=·16)

TABLE III.—Sample of 100 Women on Machines. (Period October, 1917–March, 1918).

Accidents.	Number having Accidents.	C.D.	B.D.	U.D.
0	15	5	21	14
1	16	15	4	19
2	21	22	9	18
3	10	22	13	15
4	17	17	14	11
5	8	11	12	8
6	4	5	8	5
7	2	2	7	4
8	1	1	4	2
9	2	·3	3	2
10	2	·1	2	1
11	—	·03	2	1
12	2	·01	1	·4
Total ...	100	100·44	100 (P=0)	100·4 (P=·48)

TABLE IV.—414 Women on Machines (Period October–December, 1917).

Accidents.	No. of Persons.	C.D.	B.D.	U.D.
0	296	256	313	299
1	74	122	41	69
2	26	30	33	26
3	8	5	17	11
4	4	1	7	5
5	4	·1	2	2
6	1	—	1	2
7	0	—	·1	—
8	1	—	—	—
Total ...	414	414·1	414·1 (P=0)	414 (P=·57)

TABLE V.—Random Sample of 201 Women on Machines (Period April 18th–May 7th, 1918).

Accidents.	No. of Persons.	C.D.	B.D.	U.D.
0	130	126	126	127
1	49	59	54	56
2	20	14	18	14
3	2	2	3	3
Total ...	201	201	201 (P=·60)	200 (P=·15)

TABLE VI.—Random Sample of 198 Women on Machines (Period February 4th, 1918–July 2nd, 1918).

Accidents.	No. of Persons.	C.D.	B.D.	U.D.
0	69	53	71	66
1	54	70	49	61
2	43	46	41	38
3	15	20	23	19
4	13	7	10	9
5	1	2	3	4
6	2	·4	1	1
7	1	·1	·2	·6
Total ...	198	198	198 (P=·22)	198·6 (P=·39)

TABLE VII.—Random Sample of 198 Women.
(Period February 4th—July 2nd, 1918.)

62 having Accidents in February.					136 having no Accident in February.				
Accidents.	Number of Persons.	C.D.	B.D.	U.D.	Accidents.	Number of Persons.	C.D.	B.D.	U.D.
0	27	20	22	24	0	69	62	78	65
1	14	23	19	19	1	35	49	27	45
2	11	13	12	11	2	25	19	19	18
3	6	5	6	5	3	5	5	9	6
4	3	1	2	2	4	2	1	3	2
5	1	·3	1	1					
Total	62	62	62 (P=·94)	62 (P=·93)	Total	136	136	136 (P=·16)	136 (P=·17)

TABLE VIII.—Random Sample of 100 Women (Period October, 1917—February, 1918).

50 Persons having Accidents in March.					50 Women having no Accident in March.				
Accidents.	Number of Persons.	C.D.	B.D.	U.D.	Accidents.	Number of Persons.	C.D.	B.D.	U.D.
0	8	3	18	9	0	15	7	17	12
1	11	9	2	10	1	10	14	7	13
2	8	12	4	9	2	9	14	9	10
3	10	11	6	7	3	4	9	8	7
4	3	8	7	5	4	6	4	5	5
5	4	4	5	4	5	4	2	3	2
6	1	2	4	2	6	2	·5	1	1
7	—	1	2	2					
8	2	·3	1	1					
9	2	·1	1	1					
10	—	·02	·4	·4					
11	1	·01	·2	·2					
Total	50	50	50 (P = ·0)	50 (P=·56)	Total	50	50	50 (P=·44)	50 (P=·39)

TABLE IX.—Random Sample of 116 Women (Period October—December, 1917).

55 Women having Accidents in January.					61 Women having no Accident in January.				
Accidents.	Number of Persons.	C.D.	B.D.	U.D.	Accidents.	Number of Persons.	C.D.	B.D.	U.D.
0	9	5	12	8	0	33	28	31	33
1	11	11	7	12	1	18	22	18	18
2	9	14	10	12	2	6	9	8	7
3	13	12	10	9	3	3	2	3	2
4	5	7	8	6	4	1	·3	1	1
5	3	4	5	4					
6	3	1	2	2					
7	1	·5	1	1					
8	1	·2	·3	1					
Total	55	55	55 (P=·35)	55 (P=·89)	Total	61	61	61 (P=·90)	61 (P=·87)

TABLE X.

Data.	Values of P.	
	B.D.	U.D.
Random Sample of 201 Women	·60	·15
Random Sample of 198 Women	·22	·39
62 Women having accidents in February	·94	·93
136 Women having no accidents in February ...	·16	·17
55 Women having accidents in January	·35	·89
61 Women having no accidents in January ...	·90	·87
50 Women having accidents in March	·00	·56
50 Women having no accidents in March	·44	·39
648 Women working on 6-in H.E. shell, "A" shop	·13	·39
584 Women working on 6-in. H.E. shell, "B" shop	·30	·16
100 Women on Machine work	·00	·48
414 Women on Machine work	·00	·57
750 Women on 60-lb. shrapnel	·002	·00
580 Women on 6-in. H.E. shell	·001	·002
Average of P. ...	·29	·43

TABLE XI.—Mean Number of Accidents per Month.
(Period October, 1917–March, 1918.)

Month.	50 Women having no Accident in March, 1918.	50 Women having Accidents in March, 1918.	Difference and Probable Error.
October	·42	·64	·22 ± ·10
November	·24	·74	·50 ± ·12
December	·34	·34	·0 ± ·07
January	·60	·58	·02 ± ·11
February	·34	·50	·16 ± ·09
March	—	1·36	—
Total ...	·39	·69	·30 ± ·11

TABLE XII.—Mean Number of Accidents per Month.
(Period October, 1917–January, 1918.)

Month.	61 Women having no Accident in January.	55 Women having Accidents in January.	Difference and Probable Error.
October	·43	·91	·48 ± ·11
November ...	·16	·93	·77 ± ·11
December... ...	·12	·64	·52 ± ·09
January	—	1·67	—
Total ...	·70	1·03	·33 ± ·12

TABLE XIII.—Mean Number of Accidents per Month.

(Period February, 1917–July, 1918.)

Month.	136 Women having no Accident in February.	62 Women having Accidents in February.	Difference and Probable Error.
February ...	—	1·31	
March	·06	·65	·59 ± ·04
April	·30	·45	·15 ± ·07
May	·10	·21	·11 ± ·04
June	·26	·40	·14 ± ·07
July	·01	·03	·02 ± ·02
Total ...	·15	·41	·26 ± ·06

TABLE XIV.—21 Women on Heavy Lathe Operation engaged in 1917 or earlier.

Check number.	Accidents in observed 3 months.	Accidents in previous 3 months.
4456	2	5
4453	2	1
2416	0	0
4455	0	0
2207	2	0
4714	4	4
2413	11	7
2211	1	0
2210	3	1
6707	4	1
2016	1	0
2168	0	0
4231	0	1
4274	0	0
4871	2	1
7146	0	0
2438	3	1
2418	2	2
2420	5	4
2412	1	3
4317	2	5
Totals	45	36
Means	2·14	1·71

Co-efficient of Correlation between accidents in successive* periods $= \cdot 72 \pm \cdot 07$.

* For the meaning of this term see p. 8.

TABLE XV.—22 Women on Profiling Operation engaged in 1917 or earlier.

Check number.	Accidents in observed 3 months.	Accidents in previous 3 months.
3026	1	2
3140	0	3
3012	1	1
7602	0	0
2843	1	0
3746	2	0
2692	2	3
2998	1	0
5147	1	3
7784	1	1
2996	0	0
5447	0	2
7916	1	1
7464	6	3
5444	2	1
5950	1	0
7788	1	1
7460	0	0
2864	1	1
5347	3	1
5517	0	0
7729	2	1
Total	27	24
Mean	1·23	1·09

Co-efficient of Correlation between accidents in successive periods = ·37 ± ·12.

TABLE XVI.—36 Women on Heavy Lathe Operation.

Check Number.	Accidents in observed 3 months.	Accidents in previous 3 months.
4456	2	5
4453	2	1
2416	0	0
4455	0	0
2207	2	0
4714	4	4
2413	11	7
2211	1	0
2210	3	1
6707	4	1
2016	1	0
2168	0	0
4231	0	1
4274	0	0
4871	2	1
7146	0	0

Co-efficient of Correlation between accidents in successive periods = ·69 ± 06.

TABLE XVI.—*cont.*

Check Number.	Accidents in observed 3 months.	Accidents in previous 3 months.
2438	3	1
2418	2	2
2420	5	4
2412	1	3
4317	2	5
4855	0	0
4297	0	0
2417	2	0
2349	3	1
7209	0	0
4237	1	1
6687	1	1
4607	3	0
2521	3	1
2533	3	2
7243	1	2
2433	1	2
2532	1	0
2516	1	1
4768	1	1
Total	66	48
Mean	1·83	1·33

Co-efficient of Correlation between accidents in successive periods = ·69 ± ·06.

TABLE XVII.—29 Women on Profiling Operation.

Check Number.	Accidents in observed 3 months.	Accidents in previous 3 months.
3026	1	2
3140	0	3
3012	1	1
7602	0	0
2843	1	0
3746	2	0
2692	2	3
2998	1	0
5147	1	3
7784	1	1
2996	0	0
5447	0	2
7916	1	1
7464	6	3
5444	2	1
5950	1	0
7788	1	1
7460	0	0
2864	1	1
5347	3	1
5517	0	0
7729	2	1

Co-efficient of Correlation between accidents in successive periods = ·53 ± ·09.

TABLE XVII.—*cont.*

Check Number.	Accidents in observed 3 months.	Accidents in previous 3 months.
5767	1	0
2928	0	0
5597	0	0
5446	0	0
5108	0	1
7477	3	3
6836	3	4
Total	34	32
Means	1·17	1·10

Co-efficient of Correlation between accidents in successive periods = ·53 ± ·09.

TABLE XVII. A.—Co-efficient of Correlation between Accidents in Successive Periods.

Date.	Observed 3 months and previous 3 months.	Not including persons having no accidents in previous 3 months.
Women on Heavy Lathe Operation ...	·69 ± ·06	·63 ± ·09
Women on Heavy Lathe Operation engaged in 1917 or earlier.	·72 ± ·07	·61 ± ·12
Women on Profiling Operation	·53 ± ·09	·37 ± ·14
Women on Profiling Operation engaged in 1917 or earlier.	·37 ± ·12	·18 ± ·17

TABLE XVIII.—Showing how many Accidents occurred to 36 Women on Heavy Lathe Operations during a period of 3 months in comparison with the numbers of Accidents calculated from the average relation found between Accidents in the successive periods.

Accidents.	Previous 3 months (y).	Observed 3 months (x).	
		Observed.	Calculated.[1]
0	14	9	7 0
1	12	10	10·6
2	4	7	8·8
3	1	6	4·2
4	2	2	2·3
5	2	1	1·5
6 & over.	1	1	1·5

[1] This column was calculated as follows.—From the data of Table XVI we deduce that if y be the number of accidents sustained by a person in the previous three months, and x the average number sustained in the observed three months, then $x = \cdot 8269y + \cdot 7305$. The integral numbers of accidents 0, 1, 2, etc., will be distributed around this mean in rough accordance with the normal curve of error having a standard deviation equal to $(1-r^2)^{\frac{1}{2}}$ multiplied by the standard deviation of all the y's. We can, therefore, find the distribution of accidents amongst the 14 persons who had none in the first period, the 12 who had 1 and so on. The agreement between the values so obtained and the actual distribution is excellent and measured by a value of P = ·91.

TABLE XIX.—Effect of Accidents on Weekly Output.

—	Average weekly output for March (excluding Absentees).					
	Mar. 1—Mar. 2.	Mar. 4—Mar. 9.	Mar. 11—Mar. 16.	Mar. 18—Mar. 23.	Mar. 25—Mar. 30.	Total.
40 Women having Accidents in March ...	18·97	68·3	67·95	67·7	68·72	291·64
50 Women having no Accidents in March	17·27	73·49	73·73	67·84	75·75	308·08

TABLE XX.—Weekly Output of 40 Women having Accidents in March showing Output for week of Accident.

Card No.	Mar. 1—Mar. 2.	Mar. 4—Mar. 9.	Mar. 11—Mar. 16.	Mar. 18—Mar. 23.	Mar. 25—Mar. 30.	Total.	(Accidents).
1	25	53 (1)	78	81	69	306	(1)
2	24	52 (1)	50	58	57 (1)	241	(2)
3	12	49	53 (1)	34	76	224	(1)
4	25	A	A	50 (2)	A	75	(2)
5	32	32 (1)	72	92 (1)	66	314	(2)
6	23	35	58	59 (1)	61	236	(1)
7	23 (1)	59	67	68	58	275	(1)
8	24 (1)	58	57	75	67	281	(1)
9	24	57	60 (1)	54	59	254	(1)
10	2	A	A	82 (2)	64 (1)	148	(3)
11	30 (1)	70	62	74 (1)	66	302	(2)
12	23	53	61	88 (1)	61	286	(1)
13	32 (1)	81	72 (1)	75	76 (1)	336	(3)
14	25	22 (1)	52	68	65	232	(1)
15	28 (1)	69	65	51	26 (2)	239	(3)
16	13	82 (1)	77	67	79	318	(1)
17	15	80	77	68 (1)	60	300	(1)
18	A	73	81 (2)	60 (1)	68	282	(3)
19	A	37 (1)	69	60	73	239	(1)
20	11	84	80	60 (1)	81	316	(1)
21	13	74	82 (1)	67	79	315	(1)
22	12	90	91	73 (1)	80	346	(1)
23	28	57	65	84	69 (1)	303	(1)
24	23	54	39 (1)	50	61	227	(1)
25	A	87	84 (1)	59	76	306	(1)
26	17	85	85 (1)	65	60	312	(1)
27	12	84 (1)	86	53	87	322	(1)
28	11	86	70 (1)	73	81	321	(1)
29	11	46	47	59 (1)	68 (1)	231	(2)
30	15	79 (1)	42	80 (1)	82	298	(2)
31	17	100 (1)	68	83	78	346	(1)
32	16	90 (1)	A	81	91	278	(1)
33	A	83	82 (1)	75	91	331	(1)
34	15	66	83	71	83 (1)	318	(1)
35	13	59	59	64 (1)	60	255	(1)
36	14	81	74 (1)	54	62	285	(1)
37	A	78 (1)	58 (1)	48 (1)	54	238	(3)
38	18	85	72	88 (2)	72	335	(2)
39	A	A	55	70 (1)	32 (1)	157	(2)
40	A	97 (1)	81	87	82	347	(1)

NOTE.—Numbers in brackets denote Accidents for week.

TABLE XXI.—Average Hourly Output of 22 Women on Profiling Operation engaged in 1917 or earlier.

Week ending	Hourly Output.				
	16 Women having accidents in 3 months.	6 Women having no accidents in 3 months.	Difference	±	Probable Error of Difference.
1918					
August 3 ...	4·81	4·64	+ ·17	±	·89
„ 10 ... (Holiday)	—	—	—		—
„ 17 ...	3·27	5·17	—1·90	±	·89
„ 24 ...	5·52	6·18	— ·66	±	·89
„ 31 ...	5·78	5·68	+ ·10	±	·89
September 7 ...	6·63	6·92	— ·29	±	·89
„ 14 ...	6·15	6·65	— ·50	±	·89
„ 21 ...	4·91	4·76	+ ·15	±	·89
„ 28 ...	6·03	6·18	— ·15	±	·89
October 5 ...	5·75	6·40	— ·65	±	·89
„ 12 ...	5·04	5·49	— ·45	±	·89
„ 19 ...	5·85	6·68	— ·85	±	·89
„ 26 ...	6·01	6·12	— ·11	±	·89
Average ...	5·48	5·91	— ·43	±	·26

TABLE XXII.—Average Hourly Output of 36 Women on Profiling operation.

Week ending	Hourly Output.				
	24 Women having accidents in 3 months.	12 Women having no accidents in 3 months.	Difference	±	Probable Error of Difference.
1918					
August 3 ...	5·02	4·98	+ ·04	±	·66
„ 10 ...	—	—	—		
„ 17 ...	3·96	5·04	—1·08	±	„
„ 24 ...	5·45	5·70	— ·25	±	„
„ 31 ...	5·01	5·45	— ·44	±	„
September 7 ...	6·39	6·48	— ·09	±	„
„ 14 ...	6·08	6·27	— ·19	±	„
„ 21 ...	4·86	4·73	+ ·13	±	„
„ 28 ...	6·26	6·18	+ ·08	±	„
October 5 ...	5·80	6·39	— ·59	±	
„ 12 ...	5·11	5·12	— ·01	±	„
„ 19 ...	5·68	7·13	—1·45	±	„
„ 26 ...	6·14	6·96	— ·82	±	„
Average ...	5·48	5·87	— ·39	±	·19

TABLE XXIII.—Average Hourly Output of 21 Women on Heavy Lathe Operation.

Week ending		Hourly Output.				
		15 Women having accidents in 3 months.	6 Women having no accidents in 3 months.	Difference	±	Probable Error of Difference.
1918						
August	3 ...	3·91	3·84	+ ·10	±	·56
,,	10 ...	—	—	—		
,,	17 ...	3·98	4·30	— ·32	±	,,
,,	24 ...	3·64	3·41	+ ·23	±	,,
,,	31 ...	4·20	3·98	+ ·22	±	,,
September	7 ...	4·17	4·03	+ ·14	±	,,
,,	14 ...	4·16	3·94	+ ·22	±	,,
,,	21 ...	4·38	4·11	+ ·27	±	,,
,,	28 ...	4·19	3·75	+ ·44	±	,,
October	5 ...	4·33	3·92	+ ·41	±	,,
,,	12 ...	4·36	4·06	+ ·30	±	,,
,,	19 ...	4·29	4·15	+ ·14	±	,,
,,	26 ...	4·12	3·95	+ ·17	±	,,
Average	...	4·15	3·95	+ ·20	±	·16

TABLE XXIV.—Average Hourly Output of 39 Women on Heavy Lathe Operation.

Week ending		Hourly Output.				
		29 Women having accidents in 3 months.	10 Women having no accidents in 3 months.	Difference	±	Probable Error of Difference.
1918						
August	3 ...	3·83	3·37	+ ·46	±	46
,,	10 ...	—	—	—		
,,	17 ...	3·67	4·01	— ·34	±	,,
,,	24 ...	3·66	3·62	+ ·04	±	,,
,,	31 ...	3·99	4·08	— ·09	±	,,
September	7 ...	4·09	4·01	+ ·08	±	,,
,,	14 ...	4·04	4·14	— ·10	±	,,
,,	21 ...	3·77	3·64	+ ·13	±	,,
,,	28 ...	4·14	3·91	+ ·23	±	,,
October	5 ...	3·82	3·90	— ·08	±	,,
,,	12 ...	4·30	3·99	+ ·69	±	,,
,,	19 ...	4·21	4·16	+ ·05	±	,,
,,	26 ...	4·08	4·11	— ·03	±	,,
Average	...	3·97	3·91	+ ·06	±	·13

TABLE XXV.—Accidents and hours lost through sickness by 36 Women on Profiling Operations.

Check Number.	Accidents in 3 months.	Hours lost by sickness in 3 months.
3140	0	42
7602	0	39·5
2996	0	0
5447	0	0
7460	0	21
5517	0	49·5
5571	0	28
2928	0	0
5597	0	35
5446	0	170
5559	0	14
5108	0	70·5
3026	1	7
3012	1	56·5
2843	1	14
2998	1	0
5147	1	7
7784	1	7
7916	1	0
5950	1	21
7780	1	14
2864	1	7
5564	1	0
5140	1	0
5767	1	7
3746	2	0
2692	2	7
5444	2	42
7729	2	21
5560	2	43·5
8646	2	22·5
5347	3	98
7477	3	0
5561	4	0
2689	4	22·5
7464	6	29·5

Co-efficient of Correlation between number of accidents and hours lost by sickness = $-\cdot 09 \pm \cdot 11$.

TABLE XXVI.—Accidents and hours lost through sickness by 29 Women on Heavy Lathe Operations.

Check Number.	Accidents in 3 months.	Hours lost by sickness in 3 months.
2416	0	8·5
4455	0	0
2168	0	28
4231	0	14
4274	0	0
7146	0	0
4297	0	42
7209	0	274
4855	0	0
6899	0	7

Co-efficient of Correlation between number of accidents and hours lost by sickness = $-\cdot 34 \pm \cdot 10$.

TABLE XXVI.—*cont.*

Check Number.	Accidents in 3 months.	Hours lost by sickness in 3 months.
2211	1	0
2016	1	0
2412	1	7
4237	1	7
4458	1	22·5
6687	1	161·5
2433	1	0
2532	1	133·5
6949	1	190·5
2516	1	0
4768	1	0
7243	1	0
4317	2	0
2418	2	7
4871	2	0
4456	2	0
4453	2	0
2207	2	0
2417	2	105·5
2210	3	86
2438	3	0
2349	3	8·5
2521	3	0
4607	3	8·5
2533	3	7
4714	4	0
6707	4	0
2420	5	14
2413	11	17

Co-efficient of Correlation between number of accidents and hours lost by sickness = $-\ \cdot 34 \pm \cdot 10$.

TABLE XXVII.—Accidents and Ages of 35 Women on Profiling Operation.

Check Number.	Accidents in 3 months.	Age of Person.
3140	0	25
7602	0	20
2996	0	18
5447	0	25
7460	0	32
5517	0	33
5571	0	30
2928	0	29
5597	0	22
5446	0	19
5559	0	19
5108	0	24
3026	1	22
3012	1	20
2843	1	22
2998	1	22
5147	1	19
7784	1	20
7916	1	20
5950	1	26
7788	1	30
5564	1	24
5140	1	40

Co-efficient of Correlation between number of accidents and age = $-\ \cdot 19 \pm \cdot 11$.

TABLE XXVII.—*cont.*

Check Number.	Accidents in 3 months.	Age of Person.
5767	1	19
3746	2	22
2692	2	28
5444	2	32
7729	2	23
5560	2	28
8646	2	22
5347	3	24
7477	3	19
5561	4	20
2687	4	23
7464	6	19

Co-efficient of Correlation between number of accidents and age = $- \cdot 19 \pm \cdot 11$

TABLE XXVIII.—Accidents and Ages of 39 Women on Heavy Lathe Operation.

Check Number.	Accidents in 3 months.	Age of Person.
2416	0	34
4455	0	31
2168	0	21
4231	0	19
4274	0	20
7146	0	22
4297	0	27
7209	0	22
4855	0	29
6899	0	36
2211	1	37
2016	1	22
2412	1	19
4237	1	19
4458	1	21
6687	1	37
2433	1	33
2532	1	35
6949	1	33
2516	1	37
4768	1	34
7243	1	21
4317	2	19
2418	2	22
4871	2	24
4456	2	37
4453	2	44
2207	2	36
2417	2	29
2210	3	21
2438	3	20
2349	3	18
2521	3	19
4607	3	22
2533	3	32
4714	4	39
6707	4	19
2420	5	20
2413	11	21

Co-efficient of Correlation between number of accidents and age = $- \cdot 18 \pm \cdot 10$.

TABLE XXIX.—Accidents and Civil state of 39 Women on Heavy Lathe Operation.

Accidents	Married.	Single.	Total.	Percentages.	
				Married.	Single.
0	4	6	10	40	60
1	8	4	12	67	33
2	3	4	7	43	57
3	1	5	6	17	83
4	1	1	2	50	50
5	—	1	1	—	100
11	1	—	1	100	—
Total ...	18	21	39	46	54

TABLE XXX.—Accidents and Civil state of 36 women on Profiling Operation.

Accidents.	Married.	Single.	Total.	Percentages.	
				Married.	Single.
0	5	7	12	42	58
1	5	8	13	38	62
2	3	3	6	50	50
3	1	1	2	50	50
4	2	—	2	100	—
5	—	—	—	—	—
6	—	1	1	—	100
Total ...	16	20	36	44	56

APPENDIX.

Methods of Calculating Distributions.

The three distributions shown in the various tables were calculated by the following methods :—

1.—*Simple Chance Distribution* (C.D.).

If N be the number of persons and n the number of accidents, the distribution has been taken to be

$$N\left(\frac{N-1}{N} + 1\right)^n \quad \ldots \quad \ldots \quad (1)$$

The terms of which are closely represented by the exponential expression :—

$$Ne^{\frac{n}{N}}\left(1 + \frac{n}{N} + \frac{\left(\frac{n}{N}\right)^2}{1.2} + \frac{\left(\frac{n}{N}\right)^3}{1.2.3} \ldots .\right) \quad \ldots \quad \ldots \quad (2)$$

when $\frac{1}{N}$ is small but $\frac{n}{N}$ finite.

The values of (2) are obtained from *Tables for Statisticians and Biometricians.* (Cambridge, 1914), pp. 113–121.

2.—*Biassed Distribution* (B.D.).

If t be assumed that the liability to accident is altered by having sustained an accident, a form of distribution which can be used is to compute the numbers having 1, 2, . . . accidents from

$$\frac{\mathrm{N}}{s}\left(\frac{\mathrm{N}-s}{\mathrm{N}}+\frac{s}{\mathrm{N}}\right)^{n} \quad \ldots \quad \ldots \quad (3)$$

omitting the first term.

The constant s is derived from the second moment of the statistics by the equation :—

$$\mu_2 = \frac{n\{\mathrm{N}-n+s\,(n-1)\}}{\mathrm{N}^2} \quad \ldots \quad \ldots \quad (4)$$

When greater than unity it denotes an increased liability after the first accident.

3.—*Distribution of Unequal Liabilities* (U.D.).

Supposing the distribution of susceptibility to accidents to be continuous and of the form :—

$$y = y_0\, e^{-c\lambda}.\ \lambda^{r-1} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

where λ is the measure of liability or susceptibility c, r and y_0 constants ;

Then the frequencies of 0, 1, 2, &c. accidents are given by the successive terms of :—

$$\mathrm{N}\left(\frac{c}{c+1}\right)^{r}\left\{1+\frac{r}{c+1}+\frac{r\,(r+1)}{2!\,(c+1)^2}+\frac{r\,(r+1)\,(r+2)}{3!\ \ (c+1)^3}+\ .\ .\ .\ .\right\} \quad (6)$$

and r and c are obtained from the statistics from :—

$$\mathrm{M} = \frac{r}{c} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

$$\mu_2 = \frac{r\,(c+1)}{c^2} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

Where M is the mean and μ_2 the second moment about the mean of the distribution observed.

A full discussion of these, and other methods, will be given in a forthcoming paper by M. Greenwood and G. Udny Yule ; all that is necessary here is to refer the reader to the cautions given in the text of this paper respecting the applicability and interpretation of the formulæ chosen.

Wt. 3972. 3/53. J & S Ltd. Gp. 943

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1919 : *Reprinted* 1953

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S.O. Code No. 46-2-4-53