SCHEDULE RATING CONSIDERED FROM AN ACTUARIAL POINT OF VIEW.

BY

ALBERT H. MOWBRAY.

NATURE OF PROBLEM.

It is generally considered that schedule rating for compensation risks serves two purposes:

1. It promotes greater equity in the assessment of insurance cost than is possible where all risks in the same classification must take the same rate.

2. It promotes effective accident prevention work by offering rewards for better than average conditions and charging penalties for worse than average conditions.

Since it is the actuary's function to adjust rates as equitably as possible in the light of experience and to continually study and compile statistics to that end, the problem of schedule rating comes within the purview of his duties. But the burden is not upon his shoulders alone. It is shared by the safety engineer.

In the work of fixing the values of the different items entering into a schedule the actuary can take but a very small part, for the statistical data with which he works are lacking. This, however, does not relieve the profession of its share in the solution of the problem. Not only must the individual items be carefully determined, but the general relations between them must conform to sound principles. Leaving, for the present, the fixing of values for separate items to the engineers we can and should study these principles and endeavor to determine the relations which must subsist between such values in order that rates may be as equitable as possible.

An analytic study of principles and relations will serve the further purpose of pointing out the statistical studies which should be undertaken for the purpose of correcting and improving the schedule both in the accuracy of values given individual items and in the relations between such values.

ANALYSIS TO DETERMINE PRINCIPLES AND RELATIONS.

The present paper is an attempt at a first analysis along these lines.

Starting from the generally accepted formula for pure premiums,

$$\pi = L/P \tag{1}$$

we may analyze the losses by causes and write

$$\pi = \frac{l_1 + l_2 + l_3 + \cdots}{P} = \frac{l_1}{P} + \frac{l_2}{P} + \cdots + \frac{l_n}{P}.$$

If we multiply both numerator and denominator of each of these fractions by the same quantity its value is unchanged, and we may further write

$$\pi = \frac{l_1}{a_1} \times \frac{a_1}{P} + \frac{l_2}{a_2} \times \frac{a_2}{P} + \cdots + \frac{l_n}{a_n} \times \frac{a_n}{P}$$

and interpret a_k as the number of accidents due to cause k. Continuing in the same way

$$\pi = \frac{l_1}{a_1} \times \frac{a_1}{P_1} \times \frac{P_1}{P} + \frac{l_2}{a_2} \times \frac{a_2}{P_2} \times \frac{P_2}{P} + \cdots + \frac{l_n}{a_n} \times \frac{a_n}{P_n} \times \frac{P_n}{P}. \tag{2}$$

SCHEDULE RATING.

We may interpret the several factors as rates as follows:

l_k/a_k = rate of cost per accident according to cause,

a_k/P_k = accident frequency per unit of exposure according to cause,

P_k/P = rate of exposure, i. e., proportionate distribution of pay-roll according to exposure to cause.

For brevity, we may write $l_k/a_k = \lambda_k$, $a_k/P_k = \rho_k$, $P_k/P = \phi_k$ Using this notation (2) may be written

$$\pi = \sum_{k=1}^{\infty} \lambda_k \rho_k \phi_k, \tag{3}$$

where the upper limit is taken as infinity to imply that the analysis as to cause should be exhaustive. Of course, for some causes λ or ρ or ϕ may any or all be zero so that the term representing that cause drops out.

If π be the average or classification rate then π' the true rate for an individual risk will be derived in the same way,

$$\pi' = \sum_{k=1}^{\infty} \lambda'_k \rho'_k \phi'_k = \pi + \Delta\pi, \tag{3a}$$

in which

$$\lambda'_k = \lambda_k \pm \Delta\lambda_k; \quad \rho'_k = \rho_k \pm \Delta\rho_k \quad \text{and} \quad \phi'_k = \phi_k \pm \Delta\phi_k,$$

where $\Delta\lambda$, $\Delta\rho$ and $\Delta\phi$ are variable quantities dependent upon local conditions.

Then the charge or credit for departure from average conditions will be

$$\Delta\pi = \pi' - \pi = \sum_{k=1}^{\infty} (\lambda'_k \rho'_k \phi'_k - \lambda_k \rho_k \phi_k), \tag{4}$$

from which equation it appears that the charge or credit for departure from the average is to be found by considering each accident cause separately, fixing for it the charge or credit (having due regard to the three factors of proportional exposure, frequency and seriousness) for local conditions and taking the sum of such items.

In a general schedule for use with several classifications, rarely, if at all, should the charge or credit for a given change of conditions affecting the cost due to a particular hazard be a percentage of the base rate.

For this to be so for cause k we must have

$$\lambda'_k \rho'_k \phi'_k - \lambda_k \rho_k \phi_k = c\pi = c \sum_{k=1}^{\infty} \lambda_k \rho_k \phi_k,$$

where on the left-hand side $\lambda'_k \rho'_k \phi'_k$ and $\lambda_k \rho_k \phi_k$ take all possible variations within the classification limits, and on the right the range of variation is even wider.

It may be that some one condition will alter one or more factors of the combination $\lambda\rho\phi$ for every cause in an approximately uniform degree. For example, we may have $\lambda'_k = (1 \pm a)\lambda''_k$ where λ'' varies according to the cause of the accident and is determined without reference to the constant condition.

Then

$$\pi' = \sum_{k=1}^{\infty} (1 \pm a)\lambda''_k \rho'_k \phi'_k = (1 \pm a) \sum_{k=1}^{\infty} \lambda''_k \rho'_k \phi'_k = (1 \pm a)\pi''. \tag{5}$$

If there be any such condition, the rate should be found by the schedule method according to formula (3a) and the effect of this condition then estimated and combined with the first result by multiplication as indicated by (5).

Nature of Factors to be Considered.

Before proceeding to consider the basis of determining the values of λ, ρ and ϕ and the relation of changes in their value to charges and credits under a schedule rating plan, it will perhaps be well to take up a few illustrations of conditions within classification limits which severally alter the value of these factors.

A part of the pure premium on "planing and moulding mills" is due to the cost of operating buzz planers or jointers. The experience available to us probably contains observations of mills in which both the old square jointer head is used and mills in which the safety cylindrical head is used. The difference between these conditions, alone, does not affect the proportion of payroll exposed (ϕ) to jointer accidents nor the frequency of such accidents corresponding to a unit of exposure (ρ). The cost per accident is very different where the cylindrical head has replaced the old type. For this cause then λ in the basis pure premium has an average value and λ' is greater or less than λ depending upon the proportion of jointers equipped with cylindrical heads.

The use of safety foot ladders is becoming more common and our pure premiums on many classifications contain an item due to the cost of ladder accidents which is based upon an average use of ladders so equipped and not so equipped. The use of such ladders does not primarily reduce the cost per accident of ladder falls, etc., (λ) nor the proportion of employers called upon to use ladders (ϕ) but does reduce the frequency of such accidents per unit of exposure (ρ). For this cause then ρ in the basis pure premium of any classification has an average value and ρ' is greater or less than ρ depending upon the proportion of ladders used which are equipped with safety feet.

The placing of a covering over a set of gears does not affect the cost per accident of gear accidents (λ) nor the frequency of gear accidents when the cover is removed (ρ) but each such cover placed where employees must pass does reduce the exposure to gear accidents (ϕ). As in the other two cases the value of ϕ in the basis pure premiums is an average value and in any individual case ϕ' is greater or less than ϕ depending upon the proportion of exposed gears. This is the factor most commonly affected by safety work.

Independent of the cause of accident prompt and efficient medical care tends to reduce the cost per accident fairly uniformly. So also malingering tends to increase it. Intelligence and safety spirit

among employees tend to reduce the exposure to all causes of accident. It is the general view that those intangible elements usually grouped under moral hazard are of this nature.

Basis of Determination. Statistics to be Accumulated.

As was said at the outset, statistical data do not exist for the solution of the problem by actuarial methods, but we may consider what should be compiled for such a solution and the advisability of attempting its compilation.

The different things to be considered and compared are indicated in equation (2) and most companies now provide for punching their cards to show the cause of the accident as well as cost. The determination of λ and variations in λ for different causes and conditions therefore does not call for any change in our statistical methods.

The determination of both ρ and ϕ depends upon our knowing the proportion of payroll exposed to each cause. The writer has heard of no attempt to get at this. We might do so by planning to punch exposure card from our inspection reports, but designing the cards would be a difficult task and preparing and tabulating them both difficult and expensive. When it was done it is doubtful whether at the present time the expense would be justified, for conditions are so rapidly changing. Perhaps as the work of laboratory testing is carried on the value of ρ for varying conditions may be found in that way. We may then, I think, undertake special studies looking to the determination of ϕ.

The Intangible Elements. Moral Hazard.

It is the tradition of underwriting practice, coming from the days when analytic rating was considered so impossible that scientific studies looking to that end were considered useless, that this element is to be determined by observing the experience of the individual risk. In our endeavor "to substitute fact for appearance, and demonstration for impression" we may well consider whether this method may properly be combined with a system of analytic rating.

Where an attempt is made to measure the moral hazard by observing the experience with the individual risk it is usual to take its value as a percentage of the difference between the actual loss ratio and an assumed standard ratio. Expressing this in accordance with

the symbols used in (5), taking π' to be the actual experience pure premium, and π to be the manual pure premium we have

$$a = c(\pi' - \pi)/\pi. \tag{6}$$

Let us assume that the pay roll observed in the individual risk has been sufficient to eliminate accidental variation* and that our schedule has correctly valued the physical hazard. Then we have from (5) for comparison with this

$$a = \frac{\pi' - \pi''}{\pi''}. \tag{7}$$

In the original New York plan of applying a rating schedule the physical items were estimated and the intangible items by the above method and the results combined by addition, the formula corresponding to (5) being

$$\pi' = \pi'' + a\pi = \pi'' + c(\pi' - \pi).$$

This will only give the same result as (5) when

$$a\pi'' = c(\pi' - \pi)$$

or

$$c = \frac{a\pi''}{\pi' - \pi}. \tag{8}$$

Since c depends upon variable quantities it will not in general be a constant. Hence this method will not in general produce the true pure premium even when the statistical data are ample.

One reason why this is an unsatisfactory method of estimating the moral hazard is shown by an inspection of the numerators of the fractions on the right of (6) and (7) remembering that $\pi'' = \pi \pm \Delta\pi$ as determined by the schedule for physical conditions. In the usual method of determining this value by comparison of loss ratios the effect of physical conditions already separately allowed for is again allowed to influence this value.

There are other reasons which cannot be demonstrated by formula, but are nevertheless cogent. Some of the more important ones are the following:

* This will be an exceedingly rare occurrence. For a discussion of the extent of pay roll necessary to give a dependable pure premium see *Proceedings*, No. 1, p. 24.

1. By reason of too small payroll exposure to furnish a dependable pure premium luck is as much, if not more, of a factor than merit in the showing over a limited term of any moderate sized plant. At a rate of $1 per $100 (which is more than the average rate in Massachusetts) it would take the entire premium on a $400,000 payroll plant to pay for one maximum value death loss. What shall be said of New York when it has been estimated that one death case may cost two or three times the Massachusetts limit? In the plant of one corporation given highest praise by all for its splendid interest in safety and welfare work such an accident did occur not long ago. It may be said that such cases are to be considered extraordinary and specially allowed for in making up the experience as they are not an indication of bad moral hazard. To say the least this would be a dangerous precedent, and where are we to draw the line? If we take this view should we not similarly modify the statistically recorded experience of risks where we believe the moral hazard bad? We can hardly justify such a course to the insured.

Indeed, looked at from this point of view, the introduction of the experience of an individual risk as an element in determining its rate seems to be an anomaly, a breaking down of the principle of distribution on which all insurance rests.

2. The experience considered must always relate to the past and the rate to the future. Human progress goes by waves. After a period of effort and advancement we relax, grow careless, slip backward, till some strong stimulus again rouses us to action. A run of bad accidents, sometimes but one, will rouse many an employer to the need of accident prevention work. When things have apparently been running smoothly for some time, look out for the crash! The use of experience to measure moral hazard not only ignores this natural law, but runs counter to it.

3. Where the employer knows that the experience with his plant affects his rate, he is tempted to suppress the reporting of minor and sometimes serious accidents and by coercion obtains an acquiescence of his employees in this policy. (See cases cited in Report on New Jersey conditions by American Association for Labor Legislation.)

At the outset of our work in this field and until we can find a better measure of the moral hazard, it might be a wise discretion to differentiate only for the physical hazard while we diligently

seek a suitable means of including these other elements. After all, is not the moral hazard to a very large degree reflected by physical conditions?

Practical Schedule Rating According to an Engineer's Schedule.

If, as it appears from the above analysis, it is impossible to test the details of a proposed schedule by compiled statistics, it may be, indeed it has been, assumed that schedule rating should not be undertaken at all. With this view I cannot agree. Absolute equity in any human affair is unknown and probably unknowable. From this point of view it is quite likely that committees of engineers, testing each item for conformity to the above principles, will from time to time construct schedules which will be entirely satisfactory so far as equity between individual risks in the same class is concerned. Doubtless such schedules will far surpass an actuarial schedule in promoting safety work.

The difficulty with such a schedule is apt to be that the result of applying it to a given body of risks will be a distortion of the average experience premium. So far as this distortion is due to changes in safety conditions since the time for which the experience was compiled, this is as it should be. Further disturbance of the basis pure premiums is a defect in the schedule and may lead to serious inequity between classifications, or may even, if the result is an unexpected general and considerable reduction, result in the insolvency of some companies.

One practical solution which has been adopted is limitation of the aggregate charges or credits. This tends to diminish the value of the schedule from the accident prevention point of view as the insured will be left to seek the easiest and cheapest way of securing the maximum reduction. Would it not be better to test the schedule in actual application to a considerable number of risks in various classifications? From these tests an approximate measure of the effect of the schedule can be obtained and this may be allowed for in the loadings added to the pure premiums to find the gross. In this way the companies would be assured fair incomes without excessive charges to the insured.

In the above discussion pure premiums only have been considered. As long as gross premiums are made by adding a uniform percentage

loading this percentage of loading may be added to each of the items to be added to or subtracted from the base rate and if this is done the final rate will have the same percentage loading. Of course, if a sum of items containing uniform percentage loading is multiplied by any quantity the product will contain the same loading. Therefore, any factor by which the built up rate is multiplied needs no loading.