EARTHQUAKE INSURANCE IN JAPAN

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Japan is one of the most earthquake-prone countries in the world and a considerable volume of earthquake insurance is written by private insurers. Therefore, a report on earthquake insurance in Japan has been prepared for the 13th ASTIN Colloquium.

We will first summarise, from recent results of seismological studies, the matters which would form the basis for a study of earthquake insurance, and then explain how this insurance actually works in Japan.

I. OCCURRENCE OF EARTHQUAKES

1. *Location and cause of earthquake*

Most of the earthquakes in the world have occurred at the following locations:

a) Ocean ridges, ocean rises and connected fracture zones

Ocean ridges and ocean rises are rifts made to the crust of the ocean beds; examples are the Mid-Atlantic Ridge, East Pacific Rise, West Chilean Ridge and Central Ridge of the Indian Ocean. It is considered that the mantle beneath the crust, after emerging from these rifts due to convection caused by subterranean heat, forms lithosphere some 70 kilometres thick and this creeps on the ocean bed at a speed of a few centimetres a year.

If there is a gap i.e. a sideway shift in the line of the rift from which the mantle emerges, a fracture zone is produced between the pieces of moving lithospheres, and at the point of the gap two lithospheres move in opposite directions, producing a "transform fault".

b) Trenches and their adjacent areas

These form a long continuous line commencing from the Atacama Trench off Chile, going to the north along the coast of South America, Central America and Mexico, continuing to Alaska, Aleutian Trench, Kuril Trench, Japan Trench, Izu and Marianas Trench, and Philippine Trench and ending at Tonga Trench and Kermadic Trench north of New Zeeland. These trenches are considered to be the places where the lithospheres, having moved from the ridges, creep down into the mantle beneath the crust.

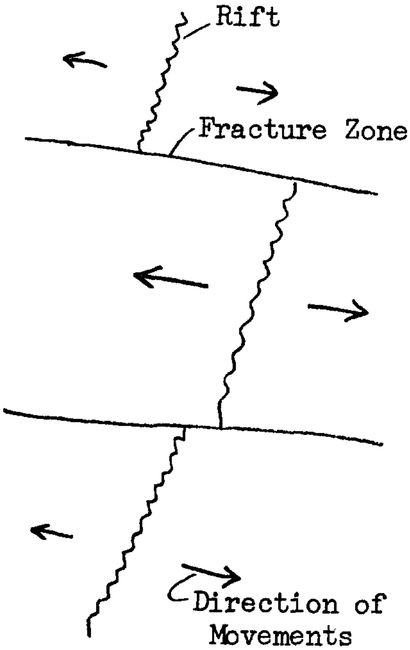

Fig. 1

c) Southern edge of the Eurasian Continent

This is a zone commencing from the Iberian Peninsula, passing through the Mediterranian Sea, Italy, Balkan Peninsula, Turkey, Central Asia, Iran, Afganistan, the Pamirs and Himalayas, continuing through Burma, off the western coast of Malaya, southern coast of Sumatra and Java and ending at the Celebes.

When explaining the cause of earthquakes, it is currently common to use mainly the Plate Tectonics Theory. For example, earthquakes occurring in the inner side of the Japan Trench (i.e. in the area between the Trench and Japan) are explained by saying

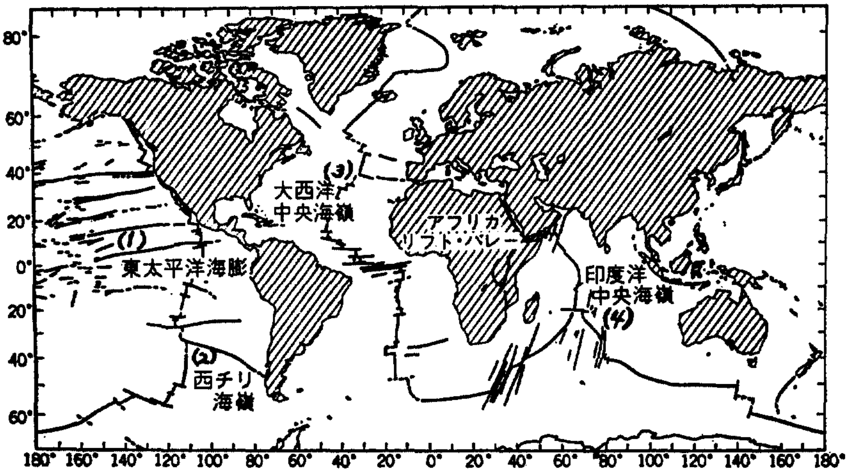

Fig. 2. Ocean Ridges and Fracture Zones
(1) East Pacific Rise (2) West Chilean Ridge
(3) Mid-Atlantic Ridge (4) Mid-Indian Ridge
(After L. R. SYKES)

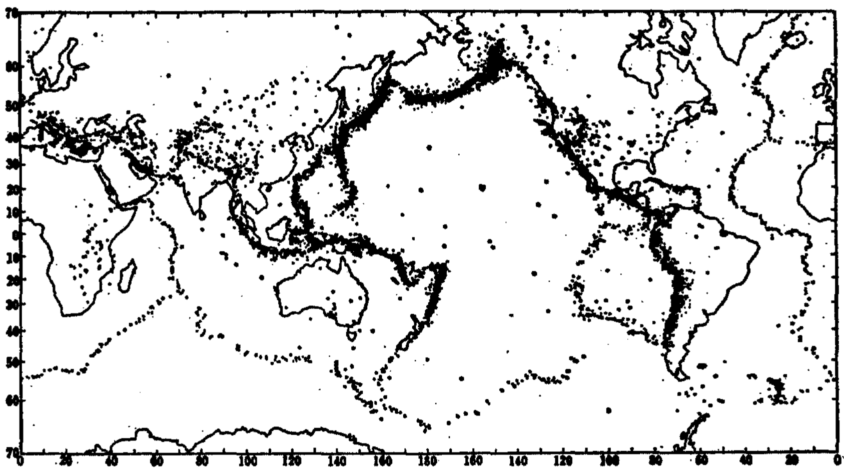

Fig. 3 Earthquakes occurring at shallow hypocentres during 1961-67
(After M. Barazangi and J. Dorman)

that they occur when strains, which are accumulated in the crust by the downward creep of the Pacific Plate beneath the Eurasian Plate, reach a limit and cause a fault in the rocks. Further, as for the earthquakes occurring in the interior of Japan, it is considered that the rock fault is caused by strains which are accumulated in the crust of the Japan Islands due to pressure from the Pacific Plate moving westward. Many of the strong earthquakes in California are thought to occur as the result of huge strains which are caused by opposite movements, at both sides of the San Andreas Fault (running from the north to the south of that State), of the North American Plate and Pacific Plate. With regard to the earthquakes at the southern edge of the Eurasian Continent, the cause is supposed to be that the continental plates moving from the south creep down beneath the Eurasian Plate at places south of the Himalayas, Alps, etc. However, the earthquakes occurring in the wide area in the interior of Eurasia, such as the Tibet plateau, Mongolian plateau and Chinese interior, do not seem to be fully explained at present by the Plate Tectonics Theory.

According to recent studies, it is considered that the "occurrence of an earthquake" is nothing but the "formation of faults" due to strains in the crust. Great earthquakes have great faults and small earthquakes small faults. The Great Kanto Earthquake (Magnitude * 7, 9) which hit Tokyo in 1923 had, it is said, a fault of some 130 kilometres in length, 65 kilometres in width, with horizontal displacement of 6 metres and vertical displacement of 3 metres. Fault displacements created at the time of great earthquakes always appear to coincide with existing faults. Existing faults have, in almost all cases, traces of repeated movements in recent geological ages. Such active faults repeat displacement by a few metres at each major earthquake, and so contribute to the forma-

(*) Magnitude is the common logarithmic expression of the maximum amplitude in micron (1/1000 mm) recorded by a standard seismograph with a periodicity of 0.8 seconds, attenuation constant of 0.8 and magnification of 280, located 100 kilometers from the epicentre.
It is commonly understood that the following empirical formula holds good between the magnitude (M) and the energy (E) of seismic waves.

$$\log_{10} E = 11.8 + 1.5\,M$$

According to this formula, the energy increases approximately 31.6 times for each 1 point's increase of the magnitude.
A certain constant relationship is observed by experience between the magnitude and the scale of faults formed by the earthquake. Generally, the length of faults is more than 100 kilometres at M8, around 10 kilometres at M7 and around 1 kilometre at M6.

tion of typical configuration. Some of them, e.g. a part of San Andreas Fault in California, are always in movement but most of the active faults move only at the time of an earthquake occurrence.

For example, the distribution of active faults in Central Japan is as shown in Fig. 4, from which it will be seen that there are indeed a great number of active faults. However, there may be dead faults among them. All the faults which are alive show locations where earthquake will occur sometime in the future.

Fig. 4. Active Faults Configuration in Central Japan.
(After T. Matsuda and A. Okada)

The maximum magnitude of earthquakes that can actually occur is considered to be M8.5 or M8.6 and in all events within M9. This presumption is based upon the resistance of rocks forming the Earth and the nature of the force distorting the rocks.

2. Time interval of earthquakes

Earthquakes recur at the same place. Where great earthquakes have occurred in the past, a similar one will occur again in the future. There is a limit to the magnitude of strain that rocks can endure. According to measurements carried out immediately after several large earthquakes in the past, the limit of the strain in the crust is considered to be 1/10,000 (or 5/100,000 according to another theory), and the prevailing theory says that an earthquake occurs when strains reach this limit. As we can consider the speed of strain accumulation to be constant, there must be some expected values in the time intervals of earthquakes. However, as the rocks forming the crust are actually not homogeneous and as faults commence at the weakest part of the crust, it is inevitable that the time interval between two given earthquakes becomes random. For example, great earthquakes (approx. M8) in the inner side of the Japan Trench have occurred at considerably varying intervals of 100 years to 200 years at any one hypocentral region. Earthquakes (M7.5 or less) in the interior of the Japan Islands are considered to occur at an average interval of 1,000 years at any one hypocentral region.

To take the Tokyo region for example, the Great Kanto Earthquake (M7.9) in 1923 occurred at the fault running along the Sagami Trough (a small trench running from Sagami Bay to the point at which the Japan Trench is connected with the Izu-Marianas Trench). Another earthquake surmised to have had the same hypocentral region had occurred in 1703 (M8.2). The interval of this type of earthquakes is considered to be from 100 to 200 years, and if we are to forecast on this basis, we could say that the possibility of its recurrence in the near future is not very high. However, Tokyo has been hit by other types of earthquake. Damage was recorded by the earthquakes of 1894 (M7.0) and 1855 (M6.9). Although the magnitude of these two earthquakes was comparatively small, the shock was heavy as the hypocentre was at the shallow point right beneath Tokyo. These types of earthquake are also believed to recur but we cannot foresee from past records when and where such earthquakes will occur (if they occur at an interval of around 1,000 years, no reliable records are available).

Large earthquakes are always followed by aftershocks. For a period of several years after a large earthquake, say possibly 20 to 30 years, there occur a number of earthquakes and these are considered to be aftershocks. The aftershocks cease to occur when the rocks crushed by large earthquakes have been stabilized, and thenceforth the accumulation of strain resumes and continues until the next great earthquake. It appears that no earthquakes, even small ones, occur during the 20 to 30 years preceding the next large earthquake. For example, the Pacific Zone south-east of Nemuro City, Hokkaido (where an earthquake of M7.9 occurred in 1894) was, for many years, a seismicity gap in the larger Pacific area stretching from the Kuril Islands to the northern part of Japan, and was thus considered as a suspect zone; in fact, an earthquake of M7.4 occurred there in June, 1973. There are similar seismicity gaps in Pacific Zones, such as off Boso Peninsula south-east of Tokyo, off Shizuoka and off Shikoku Island.

3. *Earthquake prediction*

(1) Observation of crustal alterations

The most effective means for earthquake prediction is to observe the progress of crustal strain that will cause earthquakes, and for this purpose, it is necessary to carry out repeated and continuous measurement of deformations on the surface of the earth.

It is possible to know the progress of accumulation of strains in detail if repeated measurements are carried out starting from the time immediately after the last strong earthquake, i.e. the time when all the accumulated energies in the area have been released. If we are to assume that, as mentioned earlier, the crust of the earth can resist a maximum strain of 1/10,000, we can presume that the next large earthquake is drawing near when the repeated measurements reveal deformations approaching 1/10,000.

According to the measurements in the neighbourhood of Tokyo, it has been ascertained that during the period from the Great Kanto Earthquake of 1923 to 1971, the distance between the tip of Boso Peninsula and Ohshima Island increased by 70 cm, and that between the extremities of Boso Peninsula and of Miura Peninsula decreased by 20 cm, which means that in the course of this period a strain of 3/100,000 has been produced in this area. Therefore, if the theory is correct in assuming the maximum strain to be 1/10,000, another Great Kanto Earthquake will occur when the actual strains are further increased three times.

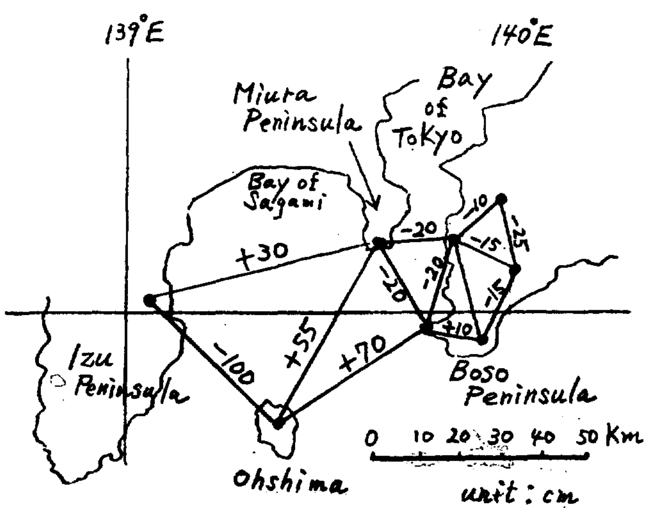

Fig. 5. Changes in distances in the area south of Tokyo (1925-1971)

It is also important to watch upthrusts and subsidences in the earth. For example, it is presumed from geological investigations that the extremity of Boso Peninsula has experienced for a very long period (for at least 6,000 years) the recurring process of upthrusts and subsidences. An earthquake of the same type as the Great Kanto caused a bulging of about 1.5 metres. This is followed by a gradual subsidence until the bulging is reduced by 80%, when it is assumed that another large earthquake occurred. For this reason, there may be a view that the next Great Kanto Earthquake could be considered to be approaching when the subsidence is again near 80%.

The crustal alteration is accelerated as an earthquake draws near, which is another important clue in earthquake prediction. In the course of accumulation of strains due to the stress added to the rocks, a plastic deformation presents itself when the deformation caused exceeds the elastic limit of the rocks, and this plastic deformation results in an increased degree of strains by adding the same unit of stress and after that a fault can occur. Therefore, if we assume that the crustal stress increases at a fixed speed, progress of the strain must be suddenly accelerated when the deformation has exceeded the elastic limit. In fact, such unusual conditions were observed in the upthrust and subsidence of the land immediately before the Niigata Earthquake in 1964. Further, there are cases where a change in the progress of strain was discovered, by means of a continuous survey of the extension and contraction of the earth crust and of the inclination of the earth surface. Actually, however, such measurements are often disturbed by subsidence due to pumping of subterranean water for industrial purposes.

(2) Other methods.

In addition to the above, there are the following methods of earthquake prediction:

a) Observation of foreshocks—Numerous foreshocks can occur before a large earthquake. Many large earthquakes can also occur suddenly without such foreshocks, but even in such cases, it is expected that microearthquakes or very small microearthquakes may be recorded if observed by high magnification seismographs developed in recent years. A problem is that, as the detectable distance of such a high efficiency seismograph is very short (20 to 60 kilometres), a measurement network should be set up at selected places where large earthquakes are likely to occur.

b) Observation of velocity of seismic waves—When stresses of the rocks reach a certain magnitude, the velocity of seismic waves (especially, that of longitudinal waves) diminishes and there occurs a change in the velocity ratio between longitudinal and transverse waves. According to observations in recent years, the longer this unusual period is, the greater is the magnitude of the earthquake that follows, and larger earthquakes are preceded by such a period for several years. The velocity of seismic waves and velocity ratio, having undergone such changes, subsequently commence to return to the original level, and an earthquake occurs when they come close to the original values. Utilizing this feature, observations of the changes in the velocity of seismic waves are being tried by means of causing artificial earthquakes.

c) Observation of terrestrial magnetism—At the time of an earthquake, a change in the terrestrial magnetism is caused as a result of the change of stress in the crust of the earth. Moreover, the earth's electrical resistance diminishes corresponding to the crustal strains (compression) preceding an earthquake. These phenomena are expected to provide useful means for earthquake prediction.

d) Observation of hot springs, subterranean water, radon, gravity, etc.—The volume and the temperature of the water from hot springs are often influenced greatly by earthquakes and there are cases where such abnormalities were observed for several months before an earthquake. The subterranean water may change its water level or become unclear. It has recently been found that the density of radon (symbol of element: *Rn*, a natural radioactive gas) in subterranean water increases abnormally before earthquakes. Furthermore, it is considered that before an earthquake, the gravity value may diminish as a result of the decrease in density of the crust due to numerous cracks produced therein, and the measurements of gravity are used as a means for predicting earthquakes.

(3) Organisation for earthquake prediction

For the purpose of earthquake prediction, it is necessary both to presume when the next earthquake is likely to occur in each area through a detailed analysis of past earthquake experience and of the actual conditions of faults on the one hand, and to carry out, on the other, continued investigations of the crustal alterations and seismic activities currently going on. In Japan, an Earthquake Prediction Research Programme was launched in 1965. With close cooperation between the Meteorological Agency, universities and other various organisations, the Programme comprises the undermentioned wide-ranged activities and the information obtained by each organization is exchanged with one another and discussed at the Coordinating Committee for Earthquake Prediction in order to attain rational judgements.

a) Observations and investigations concerning crustal alterations

(i) Measurements (triangular surveys, levellings, distance surveys, magnetic surveys, gravity surveys and surveys of isolated islands and the sea bottom)

(ii) Observations of mean sealevels
(iii) Continuous observations of crustal alterations (measurement of the inclination of the earth and of the extension and contraction of the earth in specified areas)
(iv) Geological and topographical investigations of active faults and active folds (undulations or waves displayed by the stratified rocks of the crust of the earth)

b) Observations of seismic activities
(i) Observations of large, medium and small sized earthquakes
(ii) Observations of microearthquakes (for specified areas)
(iii) Observations of very small microearthquakes (by travelling observation groups)

c) Others
(i) Measurements of changes in the velocity of seismic waves
(ii) Observations of terrestrial magnetism and terrestrial current

4. *Features of earthquake insurance*

The process of the accumulation, in an area, of the strains in the earth's crust, which leads eventually to the occurrence of an earthquake, could be compared with the life and death of a human being.

a) As death is inevitable for a human being, so does a large earthquake inevitably occur again at the hypocentral region where there was a large earthquake in the past.
b) As there is a certain expected span in the human life, so must there be a certain expected length in the interval between the last earthquake (i.e. release of energies having been accumulated up to that time, which is at the same time the beginning of an accumulation new energies) and the next one. It should, however, be realized that such expected length is different from one hypocentral region to another and that there are insufficient past records available to estimate it correctly.
c) As we can know the greater possibility of death of a human being by medical diagnosis, so can we know the greater possibility of an earthquake at a certain area by various means of earthquake prediction. Generally speaking, the certainty and

preciseness of such prediction, although very unsatisfactory at present, will be gradually improved in the future.

On the other hand, the "life" of an earthquake is not similar to human life in the following ways:

d) A human being could die in his infancy or in his youth, whereas a great earthquake does not occur before the earth's crust has reached a more advanced age (i.e. before the strains in the earth's crust approach their limit).

e) The "span of life" in the case of an earthquake (i.e. the interval between two earthquakes) is measurable in respect of each hypocentral region and not of each area suffering damage by earthquake. In the case of a city likely to be severely damaged by two or more earthquakes occurring at different hypocentral regions, we must consider the risk of earthquakes for that city by combining the different "span of life" at all such hypocentral regions.

If we take the above points into account, it may be useful to imagine some models of the structure of earthquake insurance on the analogy of life insurance. When considered in a purely technical manner, two types of earthquake insurance could be illustrated, as follows:

a) Whole-life insurance type—For this type, the premium rate will be made in the following way. The expected number of years until the occurrence of the next earthquake and the extent of damage thereby at the area in question will be estimated for each hypocentral region where an earthquake affecting the said area may occur, risk premium rate for that area will be calculated on this basis in the form of a level premium rate in respect of every such hypocentral region, and then the risk premium rates thus obtained in respect of all the relevant hypocentral regions will be totalled to arrive at the rate applicable to that area.

As for hypocentral regions where the interval between two earthquakes is very long (more than a few hundred years), it is difficult to presume, from the past records, the expected number of years until the next earthquake and therefore the rate-making will inevitably become a rough estimation. If, however, the influence of the earthquakes originating in such hypocentral regions is comparatively small to the area in question, it will not cause too great an obstacle to the rate-making.

The premium rate will be low if the policy is taken out at a time when the most important earthquake for the area in question is expected to occur only in the distant future, and the rate will become the higher, the later the time the contract is made. Besides, when it is found, through various means of prediction, that there is a very real increase in the possibility of an earthquake at an early date, it will be almost impossible for insurers to accept earthquake insurance.

b) Term insurance type—For this type, the premium rate should correspond to the then current probability of earthquakes estimated as at the time of the contract. It follows that the rate will be low as long as the time of the occurrence of an earthquake seriously affecting the area in question is clearly known to be remote (it would be nil if there were no possibility of an earthquake from any hypocentral regions), and, on the other hand, it will become difficult to provide insurance cover when the time of the occurrence is approaching. This type of insurance would be useful only against such earthquakes that originate from a hypocentral region where

(i) the time of the last earthquake or the time interval between two earthquakes is unknown, or
(ii) a fairly long time has already passed since the occurrence of the last earthquake and therefore the possibility of the next earthquake in the near future is not nil but its occurrence is not yet considered to be imminent.

In either of these two types of insurance, one of the most difficult problems is—self-evident as it is—that the number of areas exposed to the perils of serious earthquake disasters is relatively limited and, moreover, there is a great difference in the accumulation of values at each of such areas, which results in a difficulty for insurers to make a good spread of risk.

II. Scheme of Current Earthquake Insurance

1. *Two kinds of insurance are in force*

There are two kinds of earthquake insurance now in force in Japan.

a) Earthquake insurance under the "Law concerning Earthquake Insurance"

Although this insurance is written by private companies, it has the definite objective of serving to increase the stability of the people's lives in line with the State policy, and is granted only on dwelling houses (including those of which a portion is occupied as shops, offices, etc.) and household goods therein. It is run with the support of the Government's reinsurance scheme. This insurance is not reinsured with overseas markets.

b) Earthquake insurance for industrial risks

This insurance is run on a strictly private basis without relying upon any governmental facilities. It depends largely on overseas reinsurance markets.

There is a clear distinction between these two types of insurance. Dwelling risks are practically never covered by the latter type of insurance although there is no legal stipulation to prohibit it. On the other hand, it is not permitted to write industrial risks under the former type of insurance. Further, the Government has a positive policy, for the former type, to promote a wider diffusion of the protection, with which the insurance market cooperates, whereas the latter cover is granted rather passively, with each insurer limiting their acceptance.

Before trying to make a detailed explanation of the two kinds of earthquake insurances, it would be opportune to mention that, in Japan, fire caused by earthquake is excluded from the coverage of fire insurance. Wooden constructions being predominant in Japan, the greater portion of the collossal damage in the event of large earthquakes is anticipated to be attributable to subsequent fire, and therefore the Fire Insurance General Conditions specifically exclude this peril. The above two types of earthquake insurance include, for this reason, fire caused by earthquake as well as earthquake shocks.

2. *Earthquake insurance under the "Law concerning Earthquake Insurance"*

The Niigata Earthquake in 1964 aroused the keen interest of the general public in the necessity for earthquake insurance. With the passing of the Law concerning Earthquake Insurance in 1966, an insurance plan based thereon was implemented as from 1st June of the same year. Prior thereto, many studies had been made within the non-life insurance industry, which, however, could not produce fruitful results because of various difficulties in putting the plan into practice.

As this insurance was devised under the initiative of the Government with a view to contributing to the security of the general public, it has many characteristic features that are not commonly seen in ordinary commercial insurances. Undermentioned are the main points thereof.

(1) Subject matter of insurance

The subject matter should be houses for residential purposes or household goods.

(2) Way of writing

This insurance is written as a supplement to ordinary fire insurance policies or to comprehensive policies of various kinds. This cover is automatically added both to Householders' Comprehensive Insurance and to Storekeepers' Comprehensive Insurance (i.e. comprehensive insurance for stores, offices, small-sized workshops, etc.) provided, in the latter case, the policy covers a building comprising a residence portion or it covers household goods. In case of other types of insurance in the fire branch, it is optional for the policyholder to supplement the policy by this Earthquake Insurance. This cover can be granted only in conjunction with a policy of abovementioned insurances and it is not permitted to write it independently.

When this insurance was first introduced to the market in 1966, it was written only in such a way that Householders' or Storekeepers' Comprehensive Insurance policies were automatically supplemented by this cover. The purpose for doing so was to exclude adverse selection, choice acting against the insurer resulting in poorer risks prevailing in the portfolio. In fact, two kinds of adverse selection can arise in respect of earthquake insurance. One relates to the subject matter of insurance, meaning that more demands for this insurance exist on risks located in earthquake-prone areas or on risks situated on poor ground or of inferior construction. The other relates to the time of the contracts, meaning that the demand for earthquake insurance is less when the possibility of a strong earthquake is considered to be small, whereas the demand increases when it is feared that the earthquake is near at hand. One method for preventing such adverse selection would be to impose earthquake coverage on all kinds of fire insurances including ordinary fire insurance. It was not deemed appropriate, however, to impose the cost of earthquake premium on every policyholder of all these insurances, and a rule was preferred, as aforesaid, that only Householders' and Storekeepers' Comprehensive Insurance had to be supplemented by this cover.

After the introduction of this insurance, demands were increasingly raised for its greater spread and, as a result, Long-Term Comprehensive Insurance became eligible to the supplement of this cover as from 1972 and ordinary fire insurance as from 1975. This supplement being optional, adverse selection can arise. The proportion of such adverse selection in the whole earthquake portfolio, however, is expected to be fairly limited, since the earlier mentioned two comprehensive insurances automatically supplemented by earthquake cover occupy considerable portions of the business.

(3) Sum insured

The sum insured of this insurance is 30% of that of the main policy (i.e. fire or comprehensive policy supplemented by this insurance) with a limit of ¥ 2.400.000 for any one building or ¥ 1.500.000 for household goods contained in any one building. (At the outset of this insurance in 1966, these limits were ¥ 900.000 and ¥ 600.000 respectively.)

It goes without saying that the restriction of the sum insured aims at preventing huge accumulations of exposure. The uniform limits of ¥ 2.400.000 and ¥ 1.500.000 were laid down with a view to granting the minimum necessary protection to the maximum number of people, in the light of the nature of this insurance having, as its main objective, the security of the general public.

(4) Losses covered

The perils insured against under this insurance are fire, destruction, burying and washing-away caused by earthquake, volcanic eruption or tidal wave resulting therefrom (tsunami). The liability of insurers arises only for total loss, but the phrase "total loss" is to be construed flexibly here.

The reason for limiting the payments to total loss is firstly the fear of tremendous damage to which insurers would be exposed in the event of a large earthquake and secondly the intention to avoid the difficulties in claims settlement when countless policies are involved at one time in the same earthquake.

(5) Premium rate

The tariff is very simple, with the classification of only two for construction and three for location.

Construction / Location	1st Class	2nd Class	3rd Class
Superior Construction (e.g. Reinforced Concrete)	0.60%	1.35%	2.30%
Inferior Construction (e.g. Wooden)	2.10%	3.60%	5.00%

The above rates are composed of 80% for risk premium (not including claims settling expenses), 10% for agency commission and 10% for administrative expenses, of which 0.2% being for claims settling expenses and remaining 9.8% for other administrative expenses. (In fact, insurance companies are actually booking 9.8% of the earthquake insurance premium income directly as expenses.) These rates do not foresee any profits.

As the scheme of this insurance was devised with spread of protection against earthquake and easy handling in mind, the tariff was very simply composed to meet these requirements. The above classification of construction is just an integration into two groups without any other alteration of the classes of construction seen in the fire tariff. The locations are classified by prefecture, with only a few exceptions where more detailed classification is made.

The risk premium rate was calculated, on the basis of the record of 331 earthquakes having occurred in Japan during the last 467 years, from the following figures.

a) The expected loss ratio per each earthquake (i.e. proportion of the aggregate claims to the total amount insured) estimated for each location and for each class of construction, on the assumption that the above earthquakes reoccurred now in Japan under the current conditions.
b) The average frequency of the occurrence of these earthquakes during the said period (i.e. 1/467 per annum for each earthquake).

In other words, this premium rate is based on the average probability of earthquake presumed for an extremely long period of time, and does not directly reflect the probability, observed at a given time, of the advent of an earthquake in the near future. Suppose there was a person who had taken out this insurance for a long time while the risk of earthquake was deemed to be far off and discontinued it when the earthquake came close at hand. We could say that a predominant portion of his premium was offered to the benefit of other policyholders who purchased the coverage only in more recent years. Further, this insurance would lose the balance of income and outgo if only a small number of policies were demanded while the earthquake is remote in time, followed by a sudden increase of the number when it is approaching. From the viewpoint of the whole earthquake portfolio, however, these difficulties could be partly avoided, because of the aforesaid system of automatic supplement to the two kinds of comprehensive insurance. The scheme of this insurance is formulated with the intention to take balance of income and outgo over a very long period, which cannot easily be achieved by private insurers and is perhaps only possible with the involvement of the State, and the rating is also based on this idea.

(6) Reinsurance scheme

All the earthquake risks written by direct insurers are wholly reinsured with The Japan Earthquake Reinsurance Co., Ltd. (hereinafter referred to as JER), and this portfolio is protected by an Excess of Loss Reinsurance cover which is concluded between JER and the Government under the "Law concerning Earthquake Reinsurance". The limit of this cover is 50% of ¥ 120.000 million in excess of ¥ 30.000 million any one event plus 95% of ¥ 650.000 million in excess of ¥ 150.000 million any one event. Out of the JER's gross retained loss after the recovery under the Excess of Loss Reinsurance with the Government, the amount up to the first ¥ 50.000 million any one fiscal year will be borne by the original direct insurers and The Toa Fire & Marine Reinsurance Co., Ltd. according to the specified shares under a retrocession agreement, and the balance will be borne by JER for their net account.

30	120	650
Borne by private insurers (30)	50% borne by private insurers (60)	5% borne by private insurers (32.5)
	50% borne by the Government (60)	95% borne by the Government (617.5)

In 1,000 million yen)

Example 1.

If only one earthquake occurred in a fiscal year, with total claims of ¥ 80.000 million, the final liability of each party will be as follows (figures in 1.000 million yen):

— Government: $(80 - 30) \times 50\% = 25$
— Private insurers: $30 + (80 - 30) \times 50\% = 55$
of which, direct insurers and Toa-Re: 50
JER: 5

Example 2.

If two earthquakes A and B occurred in a fiscal year with total claims of ¥ 20.000 million and ¥ 200.000 million respectively, the final liability of each party will be as follows:

— Government:

For A:	Nil
For B: $(150 - 30) \times 50\% + (200 - 150) \times 95\% =$	107.5
Total:	107.5

— Private insurers:

For A:	20
For B: $30 + (150 - 30) \times 50\% + (200 - 150) \times 5\% =$	92.5
Total:	112.5
of which, direct insurers and Toa-Re:	50
JER:	62.5

Under the above scheme, JER receives reinsurance premiums equivalent to 100% of the aggregate earthquake premiums written by the direct insurers, deducting therefrom 19.8% reinsurance commission. This 19.8% covers agency commission and direct insurers' administrative expenses. (The remaining 0.2%, out of the 20% premium loading, is reserved by JER to create a fund for claims settlement expenses; the settlement of claims is to be done as a joint operation between the insurers or with close co-operation between them.) Out of these reinsurance premiums, JER pays excess of loss premiums to the Government and retrocession premiums to the direct insurers and Toa-Re.

The reinsurance premium payable to the Government is calculated as follows:

— The expected loss ratio (i.e. proportion of the aggregate claims to the total amount insured) is calculated beforehand, on the assumption that the 331 earthquakes having occurred in Japan during the last 467 years reoccurred now, in respect of each earthquake, for each location and for each class of construction.*

— At the end of each month, the amount insured then in force is totalled for each location and for each class of construction, and the above loss ratio is applied to it to obtain the expected claims amount. The latter is then totalled to estimate the aggregate claims amount for the whole involved area in respect of each earthquake. Out of this last figure, the amount of estimated recovery from the Government is calculated.

(*) This method is the same as that used for calculating the direct premium rate of this insurance. It might be added that, in the actual calculation, the above "expected claims amount" is increased by 5% (See Formula 14 at page 363).

- Both the aggregate claims amount and the amount of recovery from the Government as above are totalled for all the 331 earthquakes and the proportion of these totalled figures (of the latter to the former) is calculated. This proportion is shown as the reinsurance premium rate for the said month.
- Risk premiums written for earthquake insurance (i.e. 80% of direct premiums) are totalled for each group of policies which begin and end in the same month, and, at the same time, the aforesaid reinsurance premium rates are averaged for all the months during which these policies were in force. This average rate is applied to such total risk premium and thus the reinsurance premium for each group of policies is obtained.
- According to this method, the reinsurance premium due becomes definite only after the expiry of the relevant policies. Therefore, a deposit premium is paid in advance, and it is adjusted at expiry.

The retrocession premiums payable to direct insurers and Toa Re are 50% of the aggregate reinsurance premiums received by JER from the direct insurers (after deducting 19.8% reinsurance commissions and 0.2% for claims settling expenses). This 50% is deemed to represent an approximation of such a retrocession premium rate that would be obtained by a procedure similar to the calculation of the reinsurance premium payable to the Government.

(7) Aggregate limit of indemnity

Total amount of claims payable by all the insurers to all the insureds is limited to ¥ 800.000 million in respect of any one earthquake. In the case where the total amount of claims exceeds ¥ 800.000 million, payments will be reduced in proportion that the excess amount bears to the total amount of claims.

This limit of indemnity is decided upon every year by the Diet. At the start of this insurance it was ¥ 300.000 million, which has been increased on two occasions to reach the current ¥ 800.000 million.

(8) Deposit with JER

The direct insurers and Toa Re deposit the whole amount of retrocession premiums with JER, who in turn invests the fund on their behalf. Therefore, retrocession premiums by JER are ceded only as book entries and no actual settlement is made. Profits accruing from such investments are also reserved by JER.

(9) Premium Reserve

Insurers are required to reserve, cumulatively from year to year, the whole amount of the net premium income less net expenses as premium reserve. (For the direct insurers, this net premium income is nothing but the retrocession premiums received from JER. Regarding expenses, 19.8% is the figure laid down as being the amount they can book. This is also the figure payed as reinsurance commission by JER, leaving nothing for net expenses.) Actually, the assets corresponding to this premium reserve are all deposited with JER in accordance with the aforesaid rule. Profits accruing from the investment of the deposit fund should also be transferred into this premium reserve. Withdrawal from this reserve fund can not be made except for payment of earthquake claims.

As mentioned earlier, this insurance is subject to several limitations such as the rather moderate maximum sum insured, indemnity for total loss only and the aggregate limit of indemnity for any one earthquake. Therefore, it is not feasible with this insurance to give sufficient protection against a huge disaster that may occur in the event of a great earthquake. Moreover, in case of smaller earthquakes—which can occur rather frequently while larger ones occur only once every ten years or so—many partial losses are caused in addition to a limited number of total losses, and such partial losses are not covered by this insurance. It follows that, although actual damage by earthquake is often sustained, this insurance has little opportunity to show its usefulness. Thus, this insurance is far from being a full protection, but it was introduced, although leaving many problems unsolved, as a first step for the ambitious target of protecting the general public against the tremendous disaster and with close co-operation between the Government and the insurance industry. Since the start of this insurance in 1966, several amendments have been made, such as the increase of the limit of sums insured, increase of the aggregate limit of indemnity and optional cover in the form of supplement to ordinary fire policies. The insurance industry will also be required, for the future, to continue their efforts further to improve and expand the protection afforded by this Earthquake Insurance.

Finally, we give some figures concerning this insurance, for reference.

a) As at the end of September, 1976, the total sum insured in the whole country was approx. ¥ 5.660.000 million, and the degree of the spread of this insurance among the general public (estimated by the proportion of the number of issued policies to the number of households) is 14.54%. In Tokyo and the surrounding five prefectures (which were affected by the Great Kanto Earthquake in 1923) total sum insured is approx. ¥ 2.992.000 million and the degree of the spread 24.56%. Out of the total sum insured of ¥ 5.660.000 million, approx. ¥ 5.119.000 million relates to the cover automatically supplementing the policies of Householders' Comprehensive Insurance and Storekeepers' Comprehensive Insurance.

b) The net earthquake premium income (risk premium only after deduction of 20% for agency commission and insurers' administrative expenses) for all the insurers in 1975 calendar year was approx. ¥ 12.000 million, and the premium reserve as at 31st March, 1976 was approx. ¥ 36.400 million for all the direct insurers and Toa Re, and approx. ¥ 9.600 million for JER, totalling approx. ¥ 46.000 million for all the insurers.

(Note)

For comparison, the direct premium income for all the insurers in 1975 fiscal year for fire business (including comprehensive insurances but excluding long term insurances and Earthquake Insurance) was approx. ¥ 430.000 million and the total of premium reserves and contingency reserves as at 31st March, 1976 for all classes of business including earthquake insurance was ¥ 2.400.000 million.

c) The claims paid since the start of this insurance in 1966 up to the end of 1976 are as follows:

	(Date)	(Magnitude)	(Number of) (policies) (involved)	(Claims paid)
Ebino Earthquake No. 1	21.2.1968	M. 6.1	32 policies	¥7,085,000
Ebino Earthquake No. 2	25.3.1968	M. 5.6	1 policy	¥1,000
Hyuga-nada Earthquake	1.4.1968	M. 7.7	1 policy	¥180,000
Earthquake off the coast of Tokachi	16.5.1968	M. 7.8	175 policies	¥41,157,135
Earthquake off the coast of Izu Peninsula	9.5.1974	M. 6.8	2 policies	¥1,860,000
Oita Earthquake	21.4.1975	M. 6.4	2 policies	¥600,000
Total			213 policies	¥50,883,135

One of the reasons for claims being so few is that none of the large cities was involved in these earthquakes.

3. *Earthquake insurance for industrial risks*

Earthquake cover for industrial risks has occasionally been granted since the 1950's. The experience of the Niigata Earthquake in 1964, in which an oil refinery was involved and suffered damage, induced an extraordinary increase of demand for this cover, resulting in a huge accumulation of exposure. This cover for industrial risks is currently given in the form of extended coverage endorsement to fire policies under the following scheme.

(1) Zone system

With a view to controlling the accumulation of exposure, the whole country is divided into the following 12 zones in respect of earthquake risk.

Zone 1 Hokkaido Island

Zone 2 4 prefectures facing Sea of Japan in the north of Honshu Island

Zone 3 3 prefectures facing Pacific in the north of Honshu Island

Zone 4 4 prefectures north of Tokyo

Zone 5 3 prefectures containing the cities of Tokyo, Yokohama, Chiba and their adjacent areas

Zone 6 6 prefectures facing Pacific in the centre of Honshu Island

Zone 7 3 prefectures facing Sea of Japan in the centre of Honshu Island

Zone 8 6 prefectures containing the cities of Osaka, Kyoto, Kobe and their adjacent areas

Zone 9 5 prefectures in the west of Honshu Island
Zone 10 Shikoku Island
Zone 11 Kyushu Island
Zone 12 Ryukyu Islands

This division is based on the assumption that an area with the radius of 50 kilometres is deemed a unit of exposure. It is presumed from past experience that, in general, the area suffering serious damage by an earthquake is limited to the scope of this circle.

The insurers are always prepared to have an updated record of the accumulation of exposure at each of the above zones. The amount of this accumulation is estimated separately for direct business, for net retained lines and for reinsured lines under each treaty agreement. Also, total accumulation for the whole market is summed up periodically. On these investigations, insurers base their underwriting policy, retention and negotiation with reinsurers.

According to the recent survey, the earthquake commitments of the whole market as at the end of September, 1976 (in respect of industrial risks) amounted to ¥ 1.320.000 million for all the 12 zones and to ¥ 420.000 million for the top accumulation zone, i.e. zone 5. In addition, earthquake peril is covered under other classes of insurance, such as erection all risks, ocean cargo, ocean hull and aviation. Moreover, commitments on dwelling risks under the beforementioned Earthquake Insurance are of a considerable amount already. As for ocean marine and aviation insurances, they cover earthquake without any limitation since no exclusion is provided therefor in their policy conditions, and the total earthquake exposure under these insurances is also suspected to be great, though it is difficult to ascertain the amount of the actual accumulation because of the transient nature of the property insured.

(2) Limited indemnity plan

The Japanese market introduced what is called "limited indemnity plan" as from June, 1968 in order to avoid excessive accumulation of their earthquake commitments. Under this plan, the actual indemnity for loss or damage caused by earthquake is limited, by means of a special condition included in the policy, to a fixed percentage of such amount of indemnity that is arrived at in the ordinary way from the sum insured (sum insured of the fire policy to which the earthquake extended coverage endorsement is attached) and in accordance with all the terms and conditions of the policy (including condition of average and provisions for deductible). The difference between them is carried by the insured. At first, this plan was introduced in zone 5 only, with limited percentages of indemnity as follows:

a) For existing risks (i.e. those risks which had been insured against earthquake before this plan was introduced) 60% or less

b) For new risks (i.e. those risks which are insured against earthquake only after this plan was introduced) 30% or less

(Note) If sum insured is increased for existing risks, rule (b) is also applied to the amount of such increase.

Afterwards this plan became more strict and it was altered as follows as from April, 1975.

Zone No.	Maximum percentages of indemnity allowed under the plan	
	a) For existing risks (excluding any increase in sum insured)	b) For increases in sum insured or for new risks
5	The percentage of indemnity applied under the former policy (i.e. the policy which had been in force before this revised plan was introduced). 60% or the percentage of in-	15% (*)
6	demnity, if any, applied under the former policy, whichever is the less.	30% (*)
1, 4, 8, 9 and 12	The percentage of indemnity, if any, applied under the former policy.	30%

(*) In case of an increase being made in the sum insured for the existing risks, another restriction is applied, namely, the percentage of indemnity should be fixed at such value that the total earthquake liability under the policy after such increase may not exceed 115% (for zone 5) or 130% (for zone 6) of the earthquake liability under the former policy.

(Note) In practice, the limited percentage of indemnity is determined for the policy as a whole as an average of the percentages under a) and b) above weighted by the sums insured. If this percentage falls below 15% (for zone 5) or 30% (for zone 6), it can be raised up to 15% or 30% respectively notwithstanding the above rules.

(3) Perils insured against

Perils insured against are earthquake shock and/or fire following earthquake. Volcanic eruption is not covered. Since districts exposed to eruption risk are limited and the periodic cycle of eruption is rather constant for each volcano, it was feared that there would be a greater room for adverse selection in terms of both location and time. Tidal wave (tsunami) and flood caused by earthquake are excluded risks, but they can be covered subject to payment of additional premiums.

(4) Premium rate

The tariff for this extended coverage is composed, with seven classified locations and five classifications of construction, of the basic rate, rate for fire originating in the insured building, additional rate for damage caused by collapse of other buildings, additional rate for fire spreading from outside and additional rate for specified movables, all fixed for each class of location and construction. The actual rate applicable is arrived at by summing up these component rates. In case the property insured is situated on satisfactorily solid ground and stratum, a reduction up to a fixed percentage can be made from the rate thus arrived at. These factors of the rate are briefly outlined as follows:

a) Classification of locations: Frequency of earthquakes for each value of seismic intensity* is investigated for each district of Japan, and the whole country is divided into 7 classes of prefectures on the basis of the combined study of such frequencies.

(*) "Seismic intensity" is a measure indicating the intensity of vibration or tremor at a given place. It differs from "magnitude" which represents the size of the earthquake itself.

b) Classification of construction: Construction is classified from A to E as the following, according to the resistance of buildings both to quake and to fire:

Class A — Steel skelton building covered with iron sheet, steel skelton building covered with asbestos slate, etc.
Class B — Reinforced concrete building, steel skelton reinforced concrete building, etc.
Class C — Concrete block building reinforced with steel rods, steel skelton building covered with stone, etc.
Class D — Wooden building of one or two stories
Class E — Brick building, stone building, wooden building of more than two stories, etc.

c) Basic Rate: This rate represents the risk of collapse of the insured building due to quake, and ranges from 1.10 per mille for class A construction and class 1 location to 18.60 per mille for class E construction and class 7 location.

d) Rate for fire originating in the insured building: This rate is graded according to location, construction and occupation of the building. In general, this rate is much lower than the additional rate for fire spreading from outside.

e) Additional rate for damage caused by collapse of other buildings: This rate is applied to buildings of class A or D construction in case they are exposed to the risk of being damaged by collapse of class E construction buildings, chimneys, towers, etc., situated near the insured building.

f) Additional rate for fire spreading from outside: This rate is applied to the risks which are not isolated from other buildings.

g) Additional rate for specified movables: This rate is applied to articles which are very susceptible to shocks, such as recording or measuring instruments of various kinds, glasswares and other fragile matters.

h) Discount: A maximum 50% discount is allowed from the rate according to the condition of the ground and stratum.

It should be added that, in some cases, substantial deductibles or limits to indemnity are specified in the policy according to the conditions of the risk and to the amount insured, and special rates are worked out for such policies.

(5) Risk reserves

Under the current regulations, insurers can set aside premium reserves and contingency reserves for the policies with earthquake extended coverage endorsement only in the same proportion as they can for ordinary fire policies, and any additional reserve over such proportion would be taxed. For contingency reserves, this proportion is currently 6% of net premium income for each fiscal year, and this amount is transferred to the reserve fund cumulatively every year, subject, however, to the rule that it should be withdrawn after ten years from the time of transfer, excluding the amount corresponding to a specified percentage of the net premium income for the then current fiscal year.

III. Computation of Risk Premium Rate for Earthquake Insurances Now in Force

1. *Earthquake insurance under the "Law concerning Earthquake Insurance."*

(1) Basic idea for rating

Risk premium rating for this insurance is based upon statistical studies of the frequency and size of earthquakes. However, earthquakes causing a sizable degree of damage occur only once every few years, and great earthquakes which occur only once every hundred years or so account for an overwhelming part of the total amount of loss. For this reason, the statistical study should cover an extremely long period of time. As a matter of fact, historical records on earthquakes are available only for the relatively very short period of the more recent ages in the tremendously long history of the Earth. Moreover, many of these records are inevitably incorrect with some districts or periods omitted. For recent centuries, however, Japanese seismologists have been lucky enough to have obtained a considerable number of ancient documents with records of large earthquakes, on the basis of which they have compiled a detailed and systematic record. Since this record comprises details of damage in each district and by each earthquake, seismologists have presumed from them the location of the hypocentres of individual earthquakes and their magnitude, and made a concise list recording these features for every earthquake.

For the purpose of rating, the part of this list that covers the recent 467 years (from 20th September, 1498 to 16th June, 1964) was used for the basic data, since this part was considered comparatively reliable, and the knowledge obtained from it on frequency and size of earthquakes served as the basis for computation.

Anticipated loss should next be estimated from the size of each earthquake thus ascertained. For this purpose, a study was made for each of these earthquakes calculating the probable loss which would be caused if such an earthquake occurred now in the same place and with the same size. This calculation was made with a technological and statistical technique taking into account the following factors:

a) Seismic intensity or seismic coefficient* of the given earthquake.
b) Conditions of the ground and stratum.
c) Expected incidence of collapse of buildings.
d) Expected number of fire outbreaks, expected number of fires which cannot be prevented from spreading, and expected proportion of the area burnt down by such fires. (These vary with the season and the time of day of the occurrence of the earthquake.)
e) Expected proportion of property washed away by tsunami.
f) Expected loss ratio by volcanic eruption or landslide.
g) Stipulations in the policy conditions concerning indemnification.

As for items c) to f) above, adjustments are required to adapt the factors to the changing conditions such as increase or movement of the population, expansion of urban areas and changes in the type of architecture or in the mode of life.

One of the practical problems is that, on whatever basis the premium rate may be arrived at, insurers can cover the loss by a

(*) "Seismic coefficient" K is the ratio of the maximum acceleration (cm/sec^2) of the earthquake at a given place to the acceleration of gravity (980 cm/sec^2).

large earthquake only with such premium income having been accumulated for a very long period of time. If a large earthquake occurs before the accumulation has reached a sizable amount, insurers will face the problem of financing.

(2) Procedures for rating

Rating is done by following procedure.

(A) Estimation of loss ratio

Technological and statistical studies are made to estimate the loss ratio d_K of buildings and their contents in a given district D in the case of an earthquake of seismic coefficient K occurring in the said district. As main factors upon which the loss ratio d_K depends, expected values are worked out for collapse ratio (total collapse ratio) s_K, proportion of the burnt area, α_K, and proportion of property washed away by tsunami, β. Since this insurance covers total loss only, these ratios naturally imply the proportions of totally lost property.

The value of seismic coefficient K is obtained from the magnitude and epicentral distance of a given earthquake, in accordance with the following formula of Dr. Kawasumi:

$$I = \begin{cases} 2M - 0.30700 - 0.00183\Delta - 4.60500 \log_{10}\Delta \ (\Delta \geq 100 \text{ km}) \\ 2M - 4.03200 - 0.01668\Delta - 2 \log_{10}\Delta \ (\Delta < 100 \text{ km}) \end{cases} \quad (1)$$

I: Seismic intensity according to the "Seismic intensity scale" set up by the Japan Meteorological Agency

M: Magnitude

Δ: epicentral distance (km)

$$K = 0.258163 \times 10^{-3+0,5I}. \quad (2)$$

a) Total collapse ratio

From the result of Dr. Mononobe's study, it is known that there exists a relation of normal distribution as below between the seismic coefficient and total collapse ratio:

$$s_K = \frac{1}{\sqrt{2\pi}\sigma} \int_{-\infty}^{K} e^{-\frac{(K-K_0)^2}{2\sigma^2}} dK \quad (3)$$

K_0: average resistance of buildings to earthquake

σ: standard deviation of resistance of buildings to earthquake

b) Proportion of the burnt area, α_K

This proportion α_K is obtained in the following way from the number of buildings in the city, N, the area of the city, A, and the total collapse ratio s_K.

It is assumed that α_K can be indicated by the density of self-spreading fires, f_K/A, in the event of the occurrence of an earthquake with seismic coefficent K (it being understood that f_K stands for the number of self-spreading fires), and by the radius r of the area burnt by a single self-spreading fire.

$$\alpha_K = \varphi_1 \left(\frac{f_K}{A}, r \right) \tag{4}$$

It is assumed that f_K depends upon the total number of fire outbreaks in the city, F_K, in the case of an earthquake with seismic coefficient K, and r upon the density of buildings in the city, (N/A).

$$f_K = \varphi_2(F_K) \tag{5}$$

$$r = \varphi_3(N/A) \tag{6}$$

From the records of the Great Kanto Earthquake, the relation between F_K, N and s_K, i.e. $F_K = \varphi_4(N, s_K)$ is worked out, and then the necessary amendments are made for the change of time as well as for the possible difference of the season and the time of day of the occurrence of the earthquake.

c) Proportion of property washed away, β

It is assumed that the proportion of property washed away by tsunami, β, can be shown as the function of magnitude M and the distance from the origin of tsunami, Δ.

$$\beta = \psi(M, \Delta) \tag{7}$$

d) Aggregate loss ratio d_K in district D

From the foregoings, the loss ratio in district D is calculated as follows:

$$d_K = s_K + (1 - s_K)\alpha_K + \{1 - s_K - (1 - s_K)\alpha_K\}\,\beta \tag{8}$$

Actually, this calculation is made separately for wooden construction and non-wooden construction. For this reason, total collapse ratio in formula (3) is also worked out after obtaining the values of K_0 and σ separately for each construction.

(B) Estimation of frequency and size of earthquakes, eruptions etc.

a) As for earthquakes, frequency and magnitude are estimated from the beforementioned data concerning the 331 earthquakes during the last 467 years.

b) As for volcanic eruptions, lava flows, remote-origined tsunamis, land-slides by earthquake, etc., the number of the disasters having occurred during the same period as above is presumed from some available material as follows:

Volcanic eruptions	22
Tsunamis	39
Land-slides by earthquake	74
Total	135

c) Necessary adjustments are made as the beforementioned data does not contain any records on earthquakes in Hokkaido during the 294 years from 1498 to 1792.

(C) Calculation of the rate

On the assumption that all of the events mentioned in a), b) and c) above recurred now with the same size and severity, the total expected claims amount is calculated from the loss ratios d_K as aforementioned. This amount is divided by 467, and thus the annual risk premium is obtained.

a) The recorded 331 earthquakes

Let all these earthquakes be numbered in the order of occurrence, the seismic coefficient of the earthquake number i at district D be indicated by $K = K(i, D)$, and the amount insured at district D by A_D. Then,

— Amount of claims by earthquake i at district D is

$$A_D \cdot d_{K(i,\, D)} \tag{9}$$

— Total claims amount at district D for all the 331 earthquake is

$$\sum_{i=1}^{331} A_D \cdot d_{K(i,\, D)} \tag{10}$$

The same calculation is made for every district of Japan and then they are totalled. This totalled amount La will be:

$$La = \sum_{D} \sum_{i=1}^{331} A_D \cdot d_{K(i,\,D)} \qquad (11)$$

La stands for total expected claims amount for the whole country by the recurrence of the 331 earthquakes.

Calculations by (9) and (10) above are made separately for wooden construction and non-wooden construction. Also, the summing up by (11) above is made separately for each of 3 classes of location and for each of 2 classes of construction (therefore separately in 6 groups) in accordance with the classifications under the tariff.

b) Volcanic eruptions, lava flows, etc.

Because of the lack of basic data, an assumption is made for these perils as follows; although damage due to these events is presumed to be much less than $La/331$, i.e. the average claims amount on the 331 earthquakes mentioned in a) above, their average claims amount is assumed, on the safe side, to be 10% of that for a) above. Accordingly, the total claims amount Lb by all these 135 events is

$$Lb = \frac{La}{331} \times 0.1 \times 135 \qquad (12)$$

c) Unidentified earthquakes in Hokkaido

The number of earthquakes during the data-lacking period is supposed to be 36 on the assumption that earthquakes during this period occurred with the same frequency as those during the period for which data is available. The average claims amount thereby is assumed to be the same as in the case of b) above or $(La/331) \times 0.1$, taking into account the thinner population in Hokkaido. Total claims amount Lc is therefore:

$$Lc = \frac{La}{331} \times 0.1 \times 36 \qquad (13)$$

d) Risk premium rate

From the foregoings, the total expected claims amount L, on the assumption that all the events a), b) and c) during the last 467 years recurred now, is:

$$\begin{aligned} L &= La + Lb + Lc \\ &= La\left(1 + \frac{0.1}{331} \times 135 + \frac{0.1}{331} \times 36\right) \qquad (14) \\ &= La \times 1.05 \end{aligned}$$

Since this L is calculated separately for each of the classes appearing in the tariff as stated already, the risk premium rate (p) is obtained by dividing L by 467 and by the total amount insured for each of such classes $\sum_D A_D$. Thus

$$p = \frac{L}{467 \cdot \sum_D A_D} \qquad (15)$$

2. Earthquake insurance for industrial risks

The rating for earthquake extended coverage mentioned in the preceding chapter is done with the following basic assumptions.

a) Loss or damage due to earthquake is caused by the following 4 hazards and in the following order:
   i) Hazard of collapse of the insured building due to earthquake shock.
   ii) Hazard of suffering damage by collapse of other buildings.
   iii) Hazard of suffering damage by fire originating in the insured building.
   iv) Hazard of suffering damage by fire spreading from other objects inside or outside the premises.
b) Any one of the above hazards occurs only to the remaining portion of the property after deducting loss or damage having been suffered from the preceding hazards.

On these basic assumptions, the risk premium rate for earthquake can be obtained from the following formula:

$$\begin{aligned} r = &\sum_i f_{si} \cdot d_{si} + \sum_i f_{si}(1 - d_{si})d'_{si} + \sum_i f_{si}d_{si}(1 - d_{si})(1 - d'_{si})d_{fi} \\ &+ \max\{\sum_i f_{si} \cdot \beta_{si}(1 - d_{si})(1 - d'_{si})(1 - \alpha_{si} \cdot d_{fi})d'_{fi}, \\ &\sum_i f_{si} \cdot \gamma_{si}(1 - d_{si})(1 - d'_{si})(1 - \alpha_{si} \cdot d_{fi})d''_{fi}\} \end{aligned}$$

r: risk premium rate

s_i: Seismic intensity

f_{si}: frequency of earthquakes for a given seismic intensity

d_{si}: loss ratio by collapse of the insured building for a given seismic intensity

d'_{si}: loss ratio by collapse of other buildings for a given seismic intensity

α_{si}: frequency of fire originating in the insured building, for a given seismic intensity

d_{fi}: loss ratio by fire originating in the insured building, for a given seismic intensity

β_{si}: frequency of suffering damage from fire spreading from other objects in the same premises, for a given seismic intensity

d'_{fi}: loss ratio by fire spreading from other objects in the same premises, for a given seismic intensity

γ_{si}: frequency of suffering damage from fire spreading from outside the premises, for a given seismic intensity

d''_{fi}: loss ratio by fire spreading from outside the premises, for a given seismic intensity