CATASTROPHES AND CATASTROPHE INSURANCES

by

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1. INTRODUCTION

1.1 This paper focuses on sections of the insurance industry which are not often widely discussed. If catastrophe insurances are to be transacted successfully, a large number of different technical skills and experiences must be combined. Actuaries in the U.K. are still relatively little employed on the problems of general insurance, and are rarely involved in the complexities of these particular sections of it. It must be recognized that there is only limited scope for the application of actuarial skills in this field. However, there may be some advantage to be gained by mixing an intelligent statistical opinion with other specialized technical or practical ones when some catastrophe problems are being discussed. Before expressing a view on any topic, it is, of course, essential to learn about the background and existing conditions.

1.2 The concept of catastrophe is considered in section 2 of this paper. Potential catastrophe situations can be classified into two groups, natural hazards and man-made hazards. Each of the sections 3–9 deals with one of the principal natural hazards, giving an outline of the causes of catastrophic events, the type of losses to be expected, and the form of insurance cover likely to be available in vulnerable areas. Section 10 describes the New Zealand state scheme, which provides cover in the event of extraordinary losses from nearly all elemental perils, and war. Sections 11–16 each deal with a different type of situation where a man-made catastrophe can occur, and the insurance provisions available in each case. Having thus set the background, the later sections of the paper consider some of the aspects involved in transacting catastrophe insurances. As indicated above, the nature of this type of business is such that there is no
standard approach to many of the problems which arise. Finally, some possible future developments are mentioned.

2. WHAT IS A CATASTROPHE?

2.1 This is the sort of term which can be used to describe many different types of occurrence. Everyone thinks they know what they mean by it, but each person might find it difficult to explain their understanding of the term in general without relation to specific events. In one sense, almost every event which might have given rise to an insurance loss may be considered a catastrophe to the victim and/or their family and associates. Outside that small circle though there is usually little sense of loss to the community following a single claim event.

2.2 Primarily this paper is concerned with events which might be considered catastrophes by those in the insurance world. To a degree this means that one could ignore occurrences which would otherwise qualify as catastrophes merely because they occurred in uninsured areas. This would be somewhat unsatisfactory though, and anyway future developments might well increase the significance of such events to future insurers.

Even within the insurance market the definition of a catastrophe can vary, depending on the size of insurance concern involved. To a new life office, the death of the policyholder with the largest sum assured, or the deaths in one coach crash of many members of a group life scheme, might be of sufficient importance to verge on catastrophe, and so necessitate purchase of protection from a reinsurer. Similar types of happenings might affect any small office in any field of insurance. In this paper, the main concern will be with larger events which might affect the smooth operation of individual large companies, the insurance market of individual countries, and the world insurance and reinsurance markets.

2.3 The central features of a catastrophe might be generally agreed to be

(a) a single loss event or aggregate of losses arising from a single cause event amounting to an extremely large cost,

(b) extremely low frequency of such events as compared to that of events which lead to losses which are considered as of ordinary size.
There is room for debate as to what constitutes an 'extremely large' cost or an 'extremely low' frequency. Usually the context of the discussion will assist the fixing of such levels. It will depend on the levels considered suitable for each type of loss (levels may well vary for different lines of business within an insurance company as well as between companies and syndicates of different sorts and sizes) to what extent coverage can be offered and what measures of protection against these possible catastrophe losses should be sought. The options as to coverage and protection are discussed at length later in the paper.

For the types of event to be discussed here there should be little dispute that they can give rise to catastrophic losses. Although the insurance market will obviously be most concerned about events where the losses are insured and giving rise to large claims it would be unwise, as mentioned above, to ignore those events where losses are mainly uninsured at present. Such losses may instigate calls for increased coverage either by the existing insurance markets or by some state scheme which could affect the future development of insurance in other areas. They may also provide data on likely future losses by similar occurrences in insured areas.

2.4 The types of hazard capable of causing catastrophic events can be divided into two groups:

(a) Natural hazards. Storm, particularly windstorm, including hurricane and tornado; flood; bush fire; volcanic eruption; earthquake, both shock and ensuing fire damage.

(b) Man-made hazards. Riot; some cases of aviation or marine losses; pollution, particularly of the seas, or generally by chemical accident or explosion etc.; some types of product liability; nuclear accidents.

Each of the principal types of hazard will be discussed individually below to give a background of the underlying causes of the loss events, the areas and types of risk most likely to be affected, and the range of insurance protection likely to be available.

3. STORM

3.1 This category of hazard must be subdivided to distinguish between the type of severe storms associated with a frontal depression, which afflict this country, north-west Europe and other areas;
the even stronger tropical cyclones, which wreak havoc in many parts of the world, and the smaller-sized, but devastating, tornadoes, which are usually associated with mid-West U.S.A., but have also occurred elsewhere.

3.2 Storm and tempest is covered by U.K. property insurances. The standard fire policy used in this country covers, in its normal terms, the perils of fire (subject to certain exclusions and provisions, some of which will be discussed later); lightning and explosion (under certain circumstances only). Specified individual special perils may be covered by adding an endorsement to the fire policy. The granting of the additional cover will obviously be subject to separate underwriting considerations.

Among the special perils which may be granted are those known as 'storm and tempest', with specific exclusion of damage by escape of water from the normal confines of water courses, lakes etc.; inundation from the sea; frost; subsidence or landslip (which are regarded as perils to be covered separately); and damage to fences and gates, and usually with the application of a deductible (or excess) to each and every loss.

Flood cover will be discussed in greater depth below, but it should be noted that special perils cover against flood, even if the proximate cause was the volume of rainfall during a storm, will have been considered for underwriting separately and claims will therefore be considered only if that category of cover had been given under the policy. Such cover will be present in most cases, but not all.

Private dwellings are usually not covered by this standard policy but by comprehensive household policies, which give much wider protection including the storm and tempest cover described above, and flood protection.

3.3 There is no accepted full definition for the terms 'storm and tempest', although some guidance has been given in various judges' rulings. Particularly in Oddy v. Phoenix Assurance 1966, "Storm means storm and to me it connotes some sort of violent wind usually accompanied by rain and hail or snow. Storm does not mean persistent bad weather nor does it mean heavy rain or persistent rain by itself. Tempest in my view only means a severe storm."

3.4 Most of the storms experienced in latitudes higher than 40° north or south are frontal in origin. A line of discontinuity, called 'a front', forms where two air masses having different origins and characteristics meet. Within the temperate zones, cold air flowing
from high latitudes encounters warm air moving from subtropical regions. One of the main frontal zones is known as the Polar Front, and over the North Atlantic in winter this usually lies approximately from Florida to south-west England. The front tends to be inactive as long as the warm and cold air masses flow parallel, but when they converge the warm moist air is forced up over the cold frontal surface. This can result in the formation of much cloud and precipitation, and often starts the mechanism which leads to the development of a frontal depression. If this depression becomes severe, there will be very heavy precipitation with accompanying winds which may be very strong near the centre. The Beaufort Scale of winds defines ‘fresh gale force 8’ as having average wind speed of 39–46 m.p.h. over at least a 10 minute period. ‘Storm force 11’ requires an average wind speed of 64–75 m.p.h. for at least 10 minutes. Obviously the maximum gusts will be considerably stronger than these averages. Winds can continue at storm force long after the front has moved away. The track taken by a frontal depression is largely governed by the circulation in the atmosphere and so west-facing seaboards tend to be particularly vulnerable.

3.5 Although losses under individual policies resulting from a storm are unlikely to be of unusual size (considering the sizes of claim normally arising in the fire account), the extent of storms of this nature are such that very large numbers of claims may arise from the effects of a single storm, totalling a very large loss. Several countries may be affected by a single depression, which may be up to 1,000 miles across. In 1973, storms in western Europe cost about $150 million for insured damage.

Regarding the aggregation of claims resulting from a single large storm, all types of losses in the account will be included, whatever section of cover gives rise to them. Much damage to roofs of buildings is typical. At times a partial vacuum is created as wind flows over the roof, producing tremendous lifting pressures. Secure anchoring of all roofing materials is required. Any over-hanging eaves or ornamentation increase vulnerability. Another point to note is that farms often suffer considerable damage, but are frequently poorly insured. Underwriters are reluctant to cover exposed buildings, and farmers show reluctance to pay premiums consistently in good and hard times. Also consequential losses from storm damage tend to be underinsured, and so real total losses are very difficult to estimate. Short term forecasting can enable some measures to be taken by
individuals to limit losses where possible. However most claims are not readily preventable in that way.

Although the U.K. is subject to frequent winter storms, they are fortunately not often very severe. However, a storm causing total insured losses of about £50 million must be expected every few years. Other countries of western Europe have similar experience.

4. TROPICAL CYCLONE

4.1 This is a depression which forms under certain conditions over the seas in tropical or semi-tropical latitudes. Most coastal areas of the world between 40° north and 40° south are to varying degrees exposed to this hazard, except it seems the west coast of Africa and west and east coasts of South America. The local names for the phenomenon include hurricane, typhoon, willy-willy and cyclone.

4.2 Although there is not yet full understanding of the systems leading to the formation of tropical cyclones, certain conditions appear to be essential, including an existing low pressure circulation, usually weak; the mass of air moving on a curved path; a warm sea temperature, usually a minimum of 26°C required depending on depth, and a deep unstable layer of warm air with a high relative humidity level. Once formed they tend to move initially westward, with the centre moving at about 12 m.p.h. relative to the earth, but then to curve away from the Equator and turn towards the east, accelerating to about 25 m.p.h. The winds go round the centre of intense depression anti-clockwise in the northern hemisphere and clockwise in the southern hemisphere at speeds of 75 m.p.h. up to about 150 m.p.h. Gusts of wind may be recorded at up to 1½ times that of the mean speed being experienced. At the very centre of the storm there is usually an area of almost calm winds and broken skies. Thus a property in the path of a hurricane may first suffer severe buffetting from one direction, to be followed by a similar buffeting from the opposite direction after the centre of the disturbance has passed. The weakening effect of this can be substantial. Also a location that appeared to be protected at first may soon afterwards have become unprotected from the later winds. The area affected by the severe winds may be as much as 400 miles across, and as the relative speed of travel is slow, the duration of subjectation of any particular point to these winds may be several hours. Tropical cyclones rapidly lose their intensity as they cross land or large areas of
cold water, probably because they derive energy from the ascending warm moist air in their circulation. Thus after tracking over land for about 60 miles a cyclone would be expected to have weakened considerably, with its wind speeds usually down below 70 m.p.h.

4.3 Obviously the sheer strength of winds experienced during a hurricane will cause great damage. An approximate relationship \( P = 0.0035 V^2 \) links the force \( P \) (pressure in lbs per sq. ft) exerted by a steady wind with the wind speed \( V \) (in m.p.h.).

Another feature of the hurricane is heavy precipitation. In the winds, the rain is often blown horizontally, which can prove unusually damaging. In some conditions, heavy hail may also occur. The extreme rainfall in some areas during short periods can also lead to the inability of drainage systems to cope with the volume of water and result in severe flooding and other dangers such as landslides. Exposed coastlines are also very vulnerable. A huge mass of water can be built up ahead of a hurricane moving shorewards, and, if its arrival coincides with high tide, extensive inundation can result.

4.4 Although devastating cyclones occur all too often in other territories the major insuring nations subject to this peril are the U.S.A., Australia and Japan. The plight of the vulnerable third-world countries will be discussed later.

4.5 In the U.S.A., property damage due to catastrophe perils generally was largely not compensated prior to 1930. In the 1930’s an extended coverage endorsement including windstorm, hurricane and tornado cover was developed. Following the Federal Disaster Act of 1950, federal government funds are available to assist compensation for property damage due to catastrophe. Discussion of the effects of this occurs later. Since 1950, a large amount of windstorm cover has been given under home-owners package policies, where it is an automatically-incorporated peril. Commercial multiperil policies also give this protection. However, protection against flood must be sought separately. The National Flood Insurance Act of 1968 was an attempt to make this available to most residential and small business property owners. The Flood Disaster Protection Act of 1973 was effected to increase participation. The insurance industry marketing, policy processing and claims handling facilities are employed, but the federal government gives reinsurance and partial subsidy. However, ‘flood prone communities’ were required to adopt effective land use controls to be eligible for the scheme.
Since insurance companies showed natural reluctance to give wind-storm cover to large areas of coastal regions of the Gulf and Eastern Seaboard states, various Beach plans or FAIR plans have been introduced. Companies writing the appropriate class of fire/property business in a state are required to accept their proportion of the residential risks which seek cover but are unable otherwise to obtain it.

In addition to losses under building insurances, many claims also arise under automobile, mobile home and various marine policies. These can make estimation of a company's aggregate exposure in the various areas very complex.

4.6 Hurricane Betsy is probably the best known of the more destructive 'ladies'. She hit the Gulf states in September 1965 and cost the world insurance market over $700 million, arising from a full range of covers, including those on many marine risks and some oil rigs. Despite this huge insured loss, the full losses must have been very much greater, possibly about $3 billion. It is also terrifying to contemplate the likely cost of a repeat performance, as it has been estimated that population in the exposed areas has increased by at least 30% since the event, with an associated increase in properties exposed, in addition to the inflation of all values.

Even after hurricane Camille (August 1969, crossing the Mississippi coast and causing great flooding) and Celia (August 1970 in Texas) both costing about $225 million, the public were still reluctant to purchase extra cover. Since flood insurance had to be sought separately to the basic package provisions against windstorm, when hurricane Agnes hit in June 1972, causing some of the greatest floods ever experienced in the U.S.A., insured losses were only about $150 million, or about 5% of the total losses of about $3 billion. This particular cyclone had formed in the Gulf, crossed Florida, regained strength and recrossed the east coast to travel inland, causing floods along 4,500 miles of major rivers and damaging over 120,000 dwellings and farms.

4.7 In Australia, storm and tempest cover is included as a standard part of comprehensive householders package policies, but must be sought as a special peril addition to other fire risk covers. As in the U.S.A., State Insurance Commissioners have the power to fix maximum rates for all types of cover. Also as in the U.S.A., there is naturally a tendency for selection against insurers in the seeking of cover, and a reluctance to cover very exposed areas, although, until
this decade, it would seem that few people seriously considered that highly destructive cyclones would ever affect them.

On Christmas Eve 1971, Althea hit Townsville with winds of up to 140 m.p.h., and caused about A.$30 million of damage in 3 hours. In January 1974, Brisbane suffered A.$200 million property losses caused by Wanda, who dropped 25 inches of rain in three days causing severe floods. (A century earlier the same region had experienced rainfall of about 70 inches from a cyclone.) On Christmas Day 1974, Tracy hit Darwin, a town with a population of only about 40,000, causing extensive losses totalling about A.$300 million. Many ships in port and aircraft were damaged. Much of the destruction of buildings was because they had been designed to give comfortable living in tropical conditions with no regard to measures required to combat hurricane force winds. Following these events, a scheme for National Disaster Insurance has been proposed.

4.8 In Japan, windstorm cover has been provided under comprehensive policies for householders and small businesses since 1975, but usually with a 30% franchise and 30% indemnity ratio. For other risks, windstorm is available as an extension endorsement to fire policies, but is subject to very strict underwriting. The north-west Pacific near Japan is the origin of a large number of typhoons, an average of twelve per year. There are many very vulnerable parts of Japan, including exposed coastlines and areas of Tokyo and Osaka which lie below sea-level, as well as other regions subject to flash-flood or land-slip.

5. TORNADO

5.1 This is a phenomenon principally associated with the mid-west prairies of the U.S.A., although central Australia also experiences them fairly often, and they have occurred in other regions including Europe.

5.2 The formation and motion of a tornado are very unpredictable. The movement of a very humid, warm, air mass north from the Gulf of Mexico to meet the dry air over the great plains creates part of the necessary setting for tornadoes to be spawned. It is thought that the interaction of lines of thunderstorms and the wind distributions at intermediate levels in the atmosphere with lifting warm air masses are other triggers. A swirling commotion in low dark cloud spreads in a funnel-shape towards the ground, and, although many do not touch
the ground, when the tip does touch the earth great destruction results. Usually such a tornado travels only a few miles, at a speed across the ground of about 25–45 m.p.h., causing damage over a path only a few hundred yards wide. There is intense low pressure at the centre of the funnel, and violent rotating winds swirling inwards and upwards. The speed of the winds within such a system has not been measurable often, but it is believed that 300 m.p.h. may well be reached at times. Such winds and violent pressure changes as the tornado passes cause total destruction. Cars have been seen to be lifted 20 feet or more off the ground, and houses sucked off their foundations, with debris almost untraceable.

5.3 Hurricane Celia spawned eight tornadoes over Texas in August 1970. In April 1974, widespread storms created many tornadoes in several states causing insured losses of over $500 million in total.

It should be noted that tornadoes do also occur in Europe. In recent years small ones have occurred in Lincolnshire and near Peterborough, and in July 1968 damage costing DM 130 million was caused by a single tornado in West Germany.

6. FLOOD

6.1 There is no ready legal definition of flood, and it is usually only defined in policies where it is being specifically excluded from the cover. It is generally described as the escape of water from the normal confines of a natural or artificial water course (other than water tanks or pipes), lake, reservoir, canal or dam.

6.2 Since most flooding results from excessive rainfall, it is usual to wish to link flood with storm and tempest cover. However, some risks are obviously situated more vulnerably than most, and so careful underwriting of this hazard as a special peril endorsement to a fire policy is essential, particularly as there is a tendency for selection against the office. It is unusual, but not unknown, for flood to be specially excluded from the cover under a comprehensive package policy for highly vulnerable properties.

6.3 In some areas, the natural and artificial drainage systems have a history of inadequacy following very heavy rainfall, records of past flood levels are readily available, and future flooding must be expected in similar circumstances. In some places, measures have been taken to avert further disasters. For example, major works were
undertaken in Lynmouth following the 1968 flooding, which caused £12 million of insured damage in a relatively small area. However, new danger areas are sometimes created as increased building development may disrupt existing drainage systems causing overloading.

One of the most serious floods experienced in England was in 1953, when large areas of the East Coast were inundated. Strong on-shore winds greatly increased the effect of the seasonably high tide, and, with already high levels of water courses inland after heavy rains, produced extensive flooding behind coastal defences. It was feared that certain similar conditions could produce an even worse result, with the Thames flooding low lying areas of London. Coastal defences have been improved and the Thames barrage project is due to be completed in 1982 with the object of preventing such a catastrophe.

6.4 In the U.S.A. there are many large areas liable to flood from major waterways. The flood programme has already been referred to under hurricane covers. Once an area has been designated as 'flood prone', the community managers must impose controls to restrict land use, and enforce construction regulations for any allowed premises, in the vulnerable areas, or major forms of federal financial assistance may be withdrawn from the area. It is hoped that this will in the long term greatly reduce the flood problem.

6.5 Many areas of the third world also suffer severe flooding, which frequently causes great loss of life and damage to crops, and hence to the local economies.

7. BUSHFIRE

7.1 This is another peril which fortunately only affects a few regions of the world. The most well-known areas subject to these wide-spread conflagrations are southern France, California and Australia, where the climate and vegetation combine to give conditions where small fires can be nourished and spread rapidly to get out of the control of fire-fighting facilities. The areas affected usually contain few houses, which by their isolation would be poor fire risks in normal circumstances. Occasionally a bushfire rages towards outlying areas of population, and the possibility of this should be recognized and given special underwriting attention. However, the greatest
losses, again usually uninsured, tend to occur where, instead of rough scrub which rapidly regenerates anyway, valuable timber burns, or herds of livestock cannot escape from the holocaust.

8. VOLCANIC ERUPTION

8.1 This is not a peril which is likely to affect the U.K. Under standard fire policies, subterranean fire losses, which would include any of a volcanic origin, are specifically excluded, and any endorsement for special cover of this type is likely to be sought only against fires in coal mines or oil wells, etc.

8.2 In parts of the world where protection against this peril is sought, it is obvious that special investigation of individual cases is required. There are many types of volcanic eruption or explosion, including emission of lava, ash, mud and corrosive gases. The extent of lava flows or mud flows will depend on their viscosity and the general lie of the surrounding terrain as well as the ferocity of the eruption, but they might travel to 20 miles or so from the rim. An explosion may result in ash or mud being spread at dangerous thicknesses many miles away, and corrosive gases can be carried on the wind to damage vulnerable metals and textiles 100 miles from the volcano itself.

The type of eruption most likely to cause a great disaster appears to be the mud and ash explosion, as with the eruption of Vesuvius in AD 79, which buried Pompeii and Herculaneum and covered land several miles away with ash, making is unusable for many years; and, more recently, but fortunately in a less inhabited area, the mud eruption of Mount Tarawera, New Zealand, in 1886, which buried a wide area including the then tourist centre of Te Wairoa near Rotorua.

8.3 The science of volcanism is still far from being able to accurately judge the levels of activity to be expected in particular areas, although, where sensitive instruments have been installed within craters, some warning of a forthcoming eruption is sometimes possible. A particular danger sometimes arises where a volcano long thought to be extinct suddenly proves itself to have been merely dormant.

8.4 A further hazard, which has been associated with two of the best known eruptions of history, those of the islands of Santorini and Krakatoa, is the great sea wave, often called a tidal wave.
9. EARTHQUAKE

9.1 No-one can currently claim to have a full understanding of the causes of earthquakes. The theory of plate tectonics is now generally accepted as giving the explanation as to why earthquakes occur mainly in active belts. The outer shell of the earth is formed of a number of semi-rigid interlocking plates, which fit together so closely that, in most places, their boundaries are not sufficiently well defined as to be obvious on the surface. However, they are subject to forces from within the centre of the earth, the nature and origin of which are still the subjects of much debate and research and which cause the plates to move relative to each other. Due to the friction between the rough edges of the plates, there is a tendency for the rocks to stick, sometimes for very long periods, until such pressure has built up that a jerk, or series of jerks, suddenly occurs to release the accumulated strain. Thus, the earthquake belts of the world follow the edges of the plates, and the type of earthquake activity in any area depends on the relative motion of the plates in that region.

9.2 The type of boundary currently of relatively least importance is where a line of weakness has developed in a plate and pressure from partially molten layers below pushes the two sections apart. Most belts of this type lie along the oceanic ridges, such as the mid-Atlantic ridge on which recent activity has included the creation of the new island of Surtsey, off Iceland, in 1963. However, there are some areas where the original split occurred in a continental plate. Such regions seem to have been relatively dormant in recent decades, but should be regarded as potentially active in future. One of these with a history of damaging events in ancient times runs through the Jordan valley and the Red Sea, with a branch through the Rift valleys of Africa. Another such region is the slowly widening Gulf of California.

9.3 The majority of potentially serious earthquakes occur in belts where plates are moving towards each other. In most of these regions, an oceanic plate is pushed downwards by a more buoyant continental plate (or the relatively more buoyant of two oceanic plates), so that the boundary is marked by an offshore ocean trench. The earthquake activity in such regions occurs along a fairly wide belt. In general, shallow centred earthquakes will occur between the trench and line of current volcanic activity, which tends to follow the coastal side of a mountain range which has been forced up by the plate collision, with intermediate depth events occurring behind this line (where there are
possibly many extinct volcanoes) and deep-seated earthquakes further inland still.

The well known ‘Pacific Ring of Fire’ includes many such areas, from Japan southwards through the New Hebrides, Solomons etc., to New Zealand and along the west coasts of Central and South America and the south coast of Alaska. Other areas with this type of activity include that around the Caribbean; in the Philippines and Indonesia, and in southern Italy and Greece.

In some other regions, two continental plates meet. The collision forces up mountain ranges as both plate edges buckle. The Himalayas and the Alps were raised by the collision of the Eurasian plate with the Indian and African plates. The pressures required to continue such motion are so great that new weaknesses eventually appear within the plates, causing very complex regions of activity.

9.4 The third type of boundary, linking regions of the first two types, is the transform fault, where the relative motion is mainly in the direction of the boundary. The foci of this type of earthquake are nearly always shallow. The best known region with this type of faulting is California’s San Andreas Fault system.

9.5 Until this century, the size of an earthquake could only be judged by its observed effects and the damage caused. Nowadays many sensitive seismometers exist around the world, recording data indicating the features of individual distant earthquakes. The magnitude $M$ is usually expressed according to the Richter Scale, and can be regarded as a measure of the energy $E$ (in ergs) released by the earthquake. Their relationship is approximately, $\log_{10} E = 11.8 + 1.5M$. $M$ is usually calculated from the amplitude of traces registered on seismometers. The depth of focus and location of epicentre (point on the earth’s surface directly above the focus) are calculated using the time taken by various types of shockwave to reach several recording stations. The period of activity can also be measured instrumentally of course.

9.6 Such data does not totally indicate the severity of any particular earthquake though. The effect on any structure in the vicinity of the activity will also depend on the type and standard of its construction; the type of subsoil under it and its surroundings, particularly in the direction of the epicentre; and its distance from the epicentre.

The observable effects of an earthquake on a region can be expressed using a scale of Intensity. One of the most widely used is the Modified Mercalli Scale (the nature of which is somewhat similar to
that of the Beaufort Scale for assessing winds by their observable effects). There are twelve steps, including: I being imperceptible to humans, but registered on seismographs; VI where crockery may be broken, ornaments fall off shelves, furniture moves and cracks appear in weak plaster or weak buildings such as adobe; IX where general panic may be expected, destruction of weakly constructed buildings and serious damage to any of ordinary mortar construction, even with some reinforcement, unless designed to resist strong lateral forces, fracture of underground pipes; XII where almost total devastation may be expected as large scale changes in the structure of the ground will be experienced.

9.7 The most damage to property usually results from high magnitude shallow earthquakes, from shockwaves running near the surface of the earth. When a major earthquake originates at great depth, the area of comparable destruction is relatively small, but the shock can be felt at low intensities over a much wider area, maybe hundreds of miles away, the shock waves to these distant points passing through the earth rather than carried along its surface.

9.8 In many parts of the world exposed to this peril, government building codes have been introduced, frequently based on the SEAOC (Structural Engineers Association of California) Code. However, it is important to remember that this code was designed to protect life not property. The performance of the Balmoral Hotel, Managua, in the earthquake of 1973 is a particularly good example of this aspect. All the occupants were able to walk out relatively unscathed, but many of the columns supporting the structure at ground level were shattered, and the building had to be considered a constructive total loss. The performance of many special types of modern structure, including for example very high rise structures and oil refineries, even if subject to strict design standards has not been satisfactorily demonstrated under severe strain. Also these codes are not applied to the ordinary domestic dwellings in many areas, so that these remain highly vulnerable, and their collapse the cause of the often high earthquake death tolls. Many traditional styles of building involve adobe or weak stone walls with heavy roofs, and cannot withstand lateral movements. However, wooden structures can allow and adjust to certain limited movement, although obviously there may be a greater fire danger.

9.9 In most developed territories, the comprehensive cover policies available to householders include protection in the event of fire
following earthquake, but not for the shock damage, although this
cover might be available as a special extension at an additional
premium. Standard fire policies usually exclude all damage resulting
from an earthquake, both shock and subsequent fire, although such
cover is usually available as a special peril amendment for an addi-
tional premium. It is unlikely that such special cover would be given
except in conjunction with a basic fire policy.

9.10 It is usual to think that a damaging earthquake affecting the
U.K. is a virtual impossibility. Hence, it is not surprising that there is
little demand in this country for the available earthquake extension
coverage. Although many people are aware of the minor tremors
occasionally affecting the Midlands, near Stoke, or in Central Scot-
land, these are rarely felt at more than intensity IV and so cause
negligible damage. However, it is interesting to note that there has
been at least one fairly serious English earthquake in recent history.
On 22 April 1884, an earthquake was widely felt across south-eastern
England. The epicentre appears to have been near Wivenhoe, Essex,
where the intensity was probably VII or VIII, as many walls and
chimneys collapsed, and some cottages and church towers were
destroyed. Indeed, events like this should be borne in mind as nature
does not confine its destructive activities exclusively to the recognized
danger zones and has been known to cause several such unexpected
disasters in many similarly ‘quiet’ parts of the world.

9.11 There also seems to be a pattern of very low demand for
optional earthquake shock cover in the U.S.A. It was estimated that
in 1974 only 3% of the aggregate value of property exposed to this
peril in the U.S.A. was insured against it. Certainly less than 5% of the
property damaged in the earthquakes in Alaska in 1964 and in San
Fernando, California in 1971 was covered by private insurances.
Because of this, federal disaster funds have been made available as
grants or loans to pay for reconstruction. The equity of supplying
assistance in this way to individuals who chose not to pay for avail-
able optional cover will be discussed below. Following a major event,
there has sometimes been an increase in demand for cover, even when
premium rates have also been increased, but such business does not
usually stick for more than a few years.

In the U.S.A., standard fire policy conditions for all types of
property embrace all fire losses, thus automatically including fire
resulting from earthquake. This introduces special capacity problems
in relation to concentrations of risks, particularly in central San
Francisco and Los Angeles. Apart from the need for insurers to keep careful check on possible accumulations of risks being accepted for special earthquake shock cover, there is the conflagration hazard in such areas. Most companies have to apply limits on their fire acceptances in these centres, often using a zoning system to further subdivide their aggregations. However, to limit the extent of exposure to possible conflagration losses following an earthquake means that the basic fire business has to be turned away. This makes the decisions on appropriate zonal limits very complex.

The conflagration which broke out as a result of the 1906 San Francisco earthquake was the cause of the bulk of the losses. Obviously, the present city is very different from the one of those days. There are many opinions as to the extent and type of losses which will result from the next large event in the immediate area.

9.12 Fire also played an important role in the losses caused by the 1923 Tokyo earthquake. Japan is a highly active earthquake area. Following the Niigata earthquake in 1964, a complex plan of insurance against this peril was devised to protect residential property. A special automatic supplement was added to all fire policies on qualifying properties. However, the sum insured allowed under this supplement is strictly limited to prevent massive accumulation of losses. The rating system is based on experience of earthquakes in Japan, for which detailed records have been kept since 1498.

A complicated reinsurance scheme shares the risks between the original direct domestic insurer, the Toa Fire and Marine Reinsurance Company Limited, the Japan Earthquake Reinsurance Company Limited, and the Japanese Government.

Commercial and industrial risks can obtain limited cover against earthquake shock and fire damage as an optional extension of fire policies. However, the accumulation of exposures has made zoning over the whole country, and within the major cities, essential. In some zones the earthquake indemnity has been limited to a percentage of the fire sum insured, and the insured effectively has to coinsure the risk himself.

9.13 Any company writing several lines of business must consider its total capacity to carry earthquake costs including property, motor, marine, aviation, life, accident etc. losses. Such considerations are complicated by the difficulty of estimating the exposed to risk for most of the classes where the subjects of the insurances are mobile. Net losses will also depend on the reinsurance arrangements of the
company. These topics will be further discussed later in the paper.

9.14 Some earthquakes have been the cause of major tsunami. (This is a Japanese word for a large sea wave, now used for those of seismic origin. The term ‘tidal wave’ is sometimes misused in this context.) A severe earthquake occurring under a major body of water can cause motion in that water which becomes extremely dangerous on reaching the rising seabeds near the edges, as the height of the waves is accentuated. The waves caused by the earthquake off Chile in 1960 were over five miles wide, crossed the Pacific at about 500 mph and inflicted damage on numerous oceanic islands and the coast of Japan.

10. THE NEW ZEALAND NATIONAL PROPERTY INSURANCE SCHEME AGAINST DISASTERS

10.1 This scheme is worth a special mention as it is a particularly extensive example of Government provision of insurance cover for property against many types of disaster.

In 1941, New Zealand introduced compulsory War Damage Insurance. This insurance was to be provided automatically to all property covered by contracts of fire insurance made in New Zealand, with payment of special premiums into a separate Fund. In 1944, the required rate of special premium was reduced to 0.05%, and earthquake shock and earthquake fire were added to the hazards to be insured against under the scheme. In 1949, a Disaster Fund was created within the Earthquake and War Damage Fund to provide cover for claims arising from widespread storm and flood. The regulations were further liberalized in 1956 to cover any extraordinary disaster damage resulting from storm, flood or volcanic eruption, but excluding that caused by landslip, subsidence or erosion by the sea. The premiums (still at the 1944 rate level) are collected by the insurance companies to be passed to the Fund. The sums insured for cover under the scheme are limited to the indemnity value of the property (any additional cover may be provided by the private insurance market). Certain types of property, generally those which are not normally covered under ordinary fire policies, are not eligible for automatic cover under this scheme, although some of these properties may be allowed cover at specially negotiated rates, as may cover against landslip. If, at any time, the Fund should prove to be
inadequate to meet all claims, the amount of the deficiency will be advanced to the Fund from the Consolidated Fund.

10.2 As a result of the operation of this scheme, the portfolios of private insurers as regards disaster coverage in New Zealand are rather unusual. Some material damage cover is given on an excess-of-loss basis topping up from market values (protected under the scheme) to reinstatement values. In addition, consequential loss cover can only be provided by the private sector, and this seems to be a particularly popular type of policy, including those losses consequent upon a natural disaster, in New Zealand.

11. RIOT

11.1 In the U.K. there are five conditions essential to legally constitute a riot. In other countries such a definition often does not exist. In the U.K. and most stable countries, householders policies include cover against riot and civil commotion, and an extension to other fire policies would be readily available at a small extra premium. However, insurrection, rebellion and all war risks are excluded from all covers, and it is felt that liability in such cases should lie elsewhere. Obviously, once conditions in an area become unstable, it is very difficult to draw the line as to whether a disturbance lies within the cover or not, particularly as authorities tend to be reluctant to admit to suffering from events more serious than riots.

11.2 Following the racial disturbances of 1968 in the U.S.A., insurers withdrew from this type of cover in vulnerable areas. This led to government intervention in the form of federal stop loss reinsurance being provided in exchange for the setting up of state pools to provide the cover.

12. AVIATION AND MARINE

12.1 The straightforward hull and cargo insurance aspects will be dealt with here, the perils of pollution from or explosion of tankers, and from nuclear powered vessels being discussed in later sections.

12.2 The insurance of very large risks in the marine and aviation classes is not basically very different from that of the main body of such risks. In any portfolio the introduction of a new design or method of construction makes rating difficult until sufficient experience is available. The imbalance of the exposures when wide-bodied
jets or supertankers were first introduced required additional loadings. Although there are now sufficient in service to give fuller experience data and wider exposure, huge sums insured are involved, and, once a serious accident has occurred, the chances of a total loss are comparatively high for these classes of business.

12.3 The number of passenger lives which may be lost in a serious airline accident, with the cost of other damage on the ground as well as to the hull, increases the potential losses from this type of incident to catastrophe levels.

A number of very large marine losses have been incurred in recent years. In 1978, the Munchen was lost in mid-Atlantic giving rise to hull and cargo claims totalling over £36 million. In 1979, off Tobago, two supertankers collided with potential hull and cargo losses of over £65 million. Obviously, the markets have had to adapt their methods to provide suitable cover as exposures have climbed to these levels.

13. POLLUTION

13.1 One important aspect which particularly affects the writing of cover for this risk is moral hazard in its widest sense. Insurers need to guard against being used as substitutes for adequate care for the environment, and the provision of adequate funds for research and investment.

(A) Pollution of the Seas and Coasts

13.2 The extent of such pollution following recent tanker and oil rig accidents has been much publicized. It is generally the case that there is absolute liability on the part of shipowners without proof of negligence (barring war or the malicious acts of third parties) for any damages arising from the operation of their vessels. Various national laws and international conventions relate to oil damage liabilities. Under the 1969 Civil Liability Convention, a shipowner is liable for $160 per gross registered ton of the vessel up to a maximum of $16.8 million.

13.3 About 95% of the world tanker tonnage is covered under the Tanker Owners Voluntary Agreement on Liability for Oil Pollution. To become a member, an owner must be able to show an ability to meet claims by governments or others for damages caused by oil pollution and the costs of clearing it. This is usually provided by insurance with the International Tanker Indemnity Association or
Protection and Indemnity Clubs, but sometimes with another approved insurer. The level of cover provided is the CLC limit of liability.

In 1971, the Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution was set up by the owners of oil cargoes, usually the oil companies, to provide additional compensation where governments, third parties or owners suffer costs or claims not fully met under TOVALOP cover, taking cover up to a maximum of $36 million if required, and also indemnifying the shipowner for liability above CLC limits where the country suffering pollution is not a signatory to the CLC.

13.4 Although there are some national laws, such as the U.S. Outer Continental Shelf Lands Act, relating to pollution from offshore oil rigs, there are not as yet widespread agreements to provide cover for the damages. It has been suggested that a major blowout in the North Sea could cost up to $25 million, allowing for drilling of relief wells, dispersal of oil spilt and any coastal cleaning.

13.5 Damages for which claims may be made under the various laws relating to oil spillages do not include at present those caused to marine life, which are often very extensive.

13.6 Large volumes of other hazardous substances are also now being transported around the world, and such cargoes are occasionally lost at sea. The range of such hazardous chemicals and other substances is sufficiently wide that the costs of containment or dispersal, and of cleaning up pollution damage, may in some cases be considerable. The legal positions relating to such pollution are not clear.

(B) Other Pollution

13.7 This can be said to include discharge, dispersal, release or escape of smoke, vapours, soot, fumes, acids, alkalis, toxic chemicals, liquids or gases, waste materials or irritants, contaminants or pollutants into or upon land, the atmosphere or any water course or body of water.

13.8 Certain difficulties make the provision of insurance covering general liability for pollution particularly complex. One problem arises from the difficulty of recognizing the long term effects of exposure to the various types of pollution which might occur, such as irritant substances in the air. The harming effects of some substances
have gone unrecognized for considerable periods before damage they have caused has become apparent, e.g. use of asbestos became widespread before the dangers of accumulated inhalation of the dust was suspected. Sometimes, although the existence of inherent dangers in the use of a chemical has been known, the slow build-up of damaging quantities has gone on unsuspected, e.g. accumulation of waste mercury passing through marine life to human consumption in areas of Japan.

13.9 A further problem arises as technology advances. The range of pollutants is widened and the increased complexity of processes tends to make the possibility of escape more difficult to fully control. At times it has appeared that some industrial leaders have been aware that some pollution might result from their operations, and that certain measures could be taken to prevent it, but have chosen not to take those measures. Their reasons were usually that the possibility of pollution was extremely remote, while the costs of the prevention would be so high that competitive pricing of the industrial product would become impossible. Insurers need to take particular care where this type of situation might apply. In other cases, all the necessary precautions were thought to have been taken, but a combination of several very unlikely events has led to failure, or the possibility of a very remote occurrence has been overlooked. Indeed, where revolutionary new processes were involved, it has sometimes proved difficult for protection technology to keep pace with the dangers introduced. It is obvious that provision of insurance cover requires great technical expertise, and access to full details of all operations.

13.10 In an attempt to reflect public opinion and reduce the opportunities for moral hazard, it is usually the intention of U.K. insurers who provide cover against pollution to restrict it only to ‘sudden unintended or unexpected’ happenings, or at least to exclude ‘deliberate or continuous emissions’.

13.11 In the U.S. prior to 1966, it was possible to obtain protection even for gradual release of pollutants. Since then public opinion and stricter federal and state regulations have resulted in restricted cover being available. From 1973, the standard Comprehensive General Liability Policy excluded all property damage or bodily injury arising from all types of discharge or escape of various kinds of irritants, contaminants or pollutants unless arising from a sudden or accidental event, and offered no cover against gradual leakage or steady state discharge of pollutants. Indeed, in some states, such as New York,
pollution risk cover was banned, unless it was restricted only to sudden and accidental events. However, it has been recognized that not all unintentional events can be truly described as 'accidental'. Thus, where state and federal regulations allow, an Environmental Impairment Policy may be available to cover bodily injury, property, damage or any impairment of environmental rights protected by law caused by emission of pollutants of almost any kind, including generation of smell, noise, vibration etc. but excluding nuclear hazard, provided that there has not been knowing failure to comply with any applicable regulatory requirements. Very strict inspection and certification of all equipment is usually necessary.

14. PRODUCT LIABILITY

14.1 Insurance of this type of risk is also now very complex. Similar problems to those discussed in the section above apply to this class of business. Again long-term effects and advancing technology can lead to unforeseen claims, even when every effort has been made to prevent error. The availability of this type of cover has been severely cut back in recent years following the trend to support consumer rights to the extent that 'no-fault' liability is considered, and, particularly where the product is sold or used in the U.S.A., very high 'punitive' damage awards may be made. Where direct bodily injury or property damage claims may aggregate, with additional punitive damages, and consequential losses from withdrawal of use of faulty goods may be made, the total claims bills are potentially very high.

15. EXPLOSION

15.1 As with the previous two hazards, increasing technological development has made provision of cover against explosion much more complex. Insurers now need to have increased specialized knowledge regarding dangerous materials and processes, and full access to operational details of each risk.

15.2 Many problems similar to those discussed under pollution risks apply to explosion risks at chemical works etc. Fortunately, Flixborough was a relatively small factory in a relatively uninhabited area, but it still cost £35 million, and far more serious consequences may result from an accident at another, larger works. Obviously oil refineries present serious hazards too. A special hazard exists when a
supertanker commences discharging, or carries out degassing, in port. (At any time a small fire or stray spark on such a vessel may prove serious, but particularly so at such times.) In many terminals around the world, large numbers of bulk carriers dock, and large areas of oil storage adjoin industrial and residential areas. For example, at Kawasaki, a vast area of oil/gas/chemical bulk storage lies between the densely packed industrial and residential areas of Tokyo and Yokohama. An explosion in such a location could be extraordinarily damaging. Apart from oil tankers, many other vessels carry potentially explosive cargoes nowadays. Fortunately, although there have been some small explosions and some fires, which could have proved serious but were brought under control, no catastrophic event of this type has yet occurred.

15.3 Generally, comprehensive householder's policies include cover for any damages resulting from an explosion. Most standard fire policies provide cover against fire resulting from an explosion, but an extension may be required for other types of damage. This gives cover in the event of explosion on own or other premises. However, where any particular explosion hazard exists, special underwriting considerations apply, and in addition to cover for own property damages, protection for liability to third parties is required.

16. NUCLEAR RISKS

16.1 In a nuclear power station, heat is produced by nuclear fission and used to raise steam to drive turbines. This fission is a nuclear chain reaction as initially uranium nuclei are bombarded by neutrons causing fission or splitting, causing other neutrons to be released to keep the reaction going. The heat created in this process is carried to the boilers by a coolant, either gas or water. During the nuclear fission there is also production of intense and dangerous radiation, which, if allowed to escape, could prove lethal to man. When uranium fuel has been spent, it remains highly radioactive, and must be either directly stored securely, or may be reprocessed first into unused uranium and plutonium, which may be re-employed in fast-breeder reactors, and long-lived radioactive fission waste, which must be securely stored. Thus, not only must the reactor (the vessel in which the fission takes place) be surrounded by heavy shielding, but adequately shielded containers must be provided for long-term storage of the waste products.
16.2 The design of reactors has evolved considerably since the first were put into operation in the early 1950's, and development must be expected to continue. Rigorous safety regulations must always be complied with and, before a new reactor starts up, the designers, the operators and the inspectors must be satisfied that all possible safety measures exist. However, there is always the chance that several remotely possible events will combine to cause a catastrophic result. If any unforeseen event occurs, even if only a small section of the nuclear plant itself is involved, it is possible that severe injury, illness or death may afflict any people or animals within a considerable surrounding area, and that land and property may be contaminated, preventing access and use for a long period or involving long and expensive removal work.

16.3 Apart from nuclear power reactors, there are many other types of nuclear risks around the world, including other kinds of nuclear reactor such as those used in educational and research establishments, fuel manufacturing plants and wastage storage sites etc.

16.4 Prior to 1946, nuclear reactions tended to be kept as closely guarded secrets, particularly because of the military aspects, although research work on the generation of electricity by atomic energy was being carried out. At that time there was no legislation in the U.K. relating to nuclear risks. Since the Atomic Energy Act of 1946 first empowered the Secretary of State for Energy to promote and control the development of atomic energy, there has been a succession of national laws and international conventions. Among the most prominent are The Nuclear Installation (Licensing and Insurance) Act 1959; The Radioactive Substances Act 1960; the 1960 Paris Convention on third party liability in the field of nuclear energy; the 1963 Vienna Convention on civil liability for nuclear damage and the Nuclear Installations Acts 1965 and 1969.

For the purposes of this paper, some important provisions of this U.K. legislation may be summarized as follows. No person other than the United Kingdom Atomic Energy Authority may use any site for installing or operating a nuclear reactor or other regulated installation, or for treating irradiated matter involving extraction of uranium or plutonium, or similar processes, except under licence from the Health and Safety Executive. All keeping and use of radioactive material is subject to registration, and disposal of radioactive waste is regulated by the Department of the Environment.
16.5 The holder of a licence to operate a site has an absolute duty, regardless of fault, to ensure that no personal injury, or damage to the property of others, is caused by the radioactive, toxic, explosive or other hazardous properties of nuclear matter, or by ionizing radiations emitted from non-nuclear matter or from any waste discharged. This channelling of liability greatly assists the efficient concentration of capacity of the insurance markets. Because of the long-term nature of many nuclear hazards, particularly radiation induced diseases, which may take many years to become apparent, the period following any occurrence in which any claim must be instigated has been set at 30 years. However, the licensee is relieved of liability after 10 years, and any claims to be intimated after that time must be made to the appropriate Government department, and any compensation will then be payable from public funds. All licensees must ensure that funds are available to meet their liabilities by insurance, or by other approved means, to a minimum amount of £5 million per installation. Parliament is responsible for providing money up to an aggregate of £45 million per occurrence for claims exceeding a licensee’s available funds. Nuclear hazards can be specifically excluded under all forms of insurance cover offered to other persons, as any claims can be made on the appropriate licensee.

16.6 The public liability policy for U.K. nuclear operators normally has three sections giving

(i) the minimum £5 million Act indemnity
(ii) conventional public liability to a selected level per event, and
(iii) cover for legal and other costs.

An operator also requires employer’s liability cover, which may be provided by a conventional policy, and cover for material damage to the plant itself. A special fire policy covering fire, lightning, explosion, aircraft, earthquake, riot and civil commotion, malicious damage, storm and tempest, and any excessive temperature in the nuclear reactor caused by any sudden uncontrolled, unintentional and excessive increase or release of energy, or the failure of the cooling system, and damage to the outside surface of the nuclear reactor shield or primary cooling system or other designated property by radioactive contamination caused by escape of radioactivity from the reactor, is provided for nuclear plants.

16.7 Because of the unusual problems of nuclear insurances, and the size of claims which might arise from a single serious accident, the
U.K. insurance market constituted the British Insurance (Atomic Energy) Committee in 1957. Nuclear risks are not underwritten by individual companies or Lloyd's syndicates, but by a pool of insurers. Members of the British pools of nuclear insurers contribute fixed maximum amounts of capacity on a 'net' basis, so that no reinsurance will then be placed individually and each underwriter can know the extent of his exposure. Separate pools cover home, foreign, German and Canadian risks with separate liability and material damage sections.

16.8 Similar legislation applies in other countries participating in the conventions. Similar nuclear insurance pools have been established in over twenty countries, each representing the maximum possible insurance capacity of that market for nuclear risks. Cover is provided not only for own nation risks, but there is much co-operation between pools in the exchange of expertise and provision of reinsurance where required.

16.9 In the U.S.A., nuclear technology was a federal government monopoly until the Atomic Energy Act 1954 allowed for private ownership and operation of nuclear reactors. However, insurers were unwilling to provide full liability coverage, and so private nuclear development was delayed until after the passing of the Price–Anderson Act of 1957. This act limits the total liability of any nuclear operator for a single nuclear accident to $560 million. American insurers have also formed pools to provide nuclear insurance cover and every nuclear operator is required by law to purchase the available level of protection from the pools, or otherwise adequately guarantee that amount. The largest pool is the Nuclear Energy Liability Property Insurance Association to which stock companies belong. Mutual companies provide additional capacity through the Mutual Atomic Energy Liability Underwriters and the Mutual Atomic Energy Reinsurance Pool (for property damage cover). The levels of capacity were raised in 1979 to $300 million for property damage, $160 million for primary liability and $30 million for contingent liability. Should any incident occur where liability claims exceed the available insured amount, each operating nuclear plant in the U.S.A. is subject under federal law to contribute up to $5 million. Any further excess up to the $560 million limit will be payable by the federal government.

16.10 The rating of this type of risk is obviously very difficult. The continual development of nuclear technology has made any build-up
of a useful body of consistent experience almost impossible. Until the incident at Harrisburg, no major 'non-conventional' claims had arisen. Since stringent safety precautions are taken against all types of accidents which can be envisaged by designers and inspectors the appropriate probabilities for the most serious hazard situations are incalculable, but such 'incredible' events have occurred in other fields of hazard (e.g. Apollo 13, Flixborough) and at Harrisburg. The insurers worldwide had been subjected to increasing criticism that their rates for both property and liability cover were too high in view of the remarkably good experience up to 1979, and rates in recent years had been forced downwards because of this. This trend may now be halted.

16.11 In the U.S.A., the basic rating for both liability and property cover is calculated by the Insurance Services Office. About 70% of the liability premiums received by the pools each year is put into a reserve fund, and any not used for claims after 10 years is refunded. For property damage cover a two-tier experience rating system is applied to the basic rate. The rate modification factor is

\[ (A_n + A_e Z + E_e (1 - 0.000 - Z))/E_r \]

where
- \( A_n \) = actual 'normal' claim loss ratio calculated over latest 10 years
- \( A_e \) = actual 'excess' claim loss ratio calculated over latest 20 years
- \( Z \) = credibility factor for 'excess' claims
- \( E_e \) = expected 'excess' claim loss ratio
- \( E_r \) = total expected loss ratio = 1 - current expense ratio

Loss ratios are calculated using earned premiums adjusted to eliminate any past premium modifications allowed.

\[ Z = P/(P + K) \]

where
- \( P \) = adjusted earned premiums over latest 20 years
- \( K \) = constant, initially set at $500 million

The assumed level of division between 'normal' and 'excess' claims, the allocation of premium between the notional sections of cover, and the expense ratio to be allowed are subject to annual review.

The impact on this system of the Harrisburg incident will be considerable. It will be some time before the accuracy of the original estimate of $140 million for own property damage and costs of
decontamination can be judged. If the damage should prove to be more serious, the $300 million limit of cover could be exceeded. Indeed this plant is relatively small, and several existing plants cost $2,000 million, showing the comparative inadequacy of available cover. Fortunately, the containment system seems to have prevented more than a tiny amount of radiation escaping into the atmosphere. Even so, $2 million has already been paid under liability claims for displacement expenses, lost wages, business interruption, etc., and several claims have been submitted for the maximum limit allowed. As a 20-year time limit for notification of claims is allowed under the Price-Anderson Act, the final total cannot be known until well after that time has elapsed. There are now many protesters who say that $560 million would be very inadequate compensation in the event of a major accident.

16.12 The transportation of any nuclear substances is also subject to strict regulations. The nuclear operator is held strictly liable in all events and is assumed to have some control over the activities and safeguards of his carrier. Therefore, it is usual for the operator and carrier to be insured jointly for special carrier insurance. For international transit, each territory may make separate legal demands for insurance, and so co-operation between various nuclear pools is required. It is usual to require every container of nuclear substances to be clearly marked and specially stowed according to International Atomic Energy Agency regulations, or similar, and for specific agreement to any particular passage to be required from the relevant authority.

16.13 The 1962 Brussels Convention on liability of operators of nuclear ships states that such operators will be absolutely liable for any nuclear damage on proof that it was caused by a nuclear incident involving the nuclear fuel of, or radioactive products or waste produced by, such a ship, up to a limit of 1,500 million gold francs per incident, and must maintain insurance, or other guarantee, to cover such liability.

17. PREMIUM CALCULATIONS

17.1 It has been said that there are three primary principles which should underlie any premium basis

(i) the total income should be adequate to cover the liabilities and expenses being incurred by the insurer; but
(ii) premiums should not be above levels which reasonably reflect the cost of benefits given to insureds; and
(iii) the premium structure should ensure fairness between the various policyholders by reflecting differing levels of risk involved.

Unfortunately, it is difficult to avoid problems arising under all these principles when trying to devise rates for catastrophe covers.

17.2 Various seemingly scientifically based theoretical methods of premium calculation have been suggested for insurances against the elemental perils. The end product is usually presented as a premium rate formula similar to this

\[
P \text{ (rate } \% \text{)} = \frac{1}{1 - e} \left[ \sum \frac{EL_i}{SI} \times \frac{1000}{R_i} \times l_i + L \right] ,
\]

where factor \(1/(1 - e)\) should provide for all general administration expenses, commission, any survey costs and costs of any outside technical advice in risk assessment required and for insurer's profit. In view of the unusually high risk and associated free reserve provision requirements, it seems justifiable for shareholders to expect a somewhat higher than normal provision for profit for providing cover of this nature;

summation is over all classifications of intensity \(I\) at which damage may arise;

\(EL_i/\text{SI}\) is the expected loss factor resulting from an event at level \(I\) of intensity;

\(R_i\) is the expected return period for events at level \(I\) of intensity; and terms \(l_i\) and \(L\) are loadings to allow for uncertainty in the determination of other factors in the formula.

Usually \(P\) will be a rate per annum so that \(R_i\) will be in years. However, where the period of exposure is not a year, and the risk is not constant over the exposed period, as is often the case with engineering or construction covers, special care will be needed in deciding on appropriate \(R_i\) and \(EL_i\) factors (possibly splitting the period involved and introducing an extra summation).

17.3 It may be no simple matter to decide initially on suitable classifications of intensity which may be used in the calculations. For earthquakes the Mercalli Scale may be appropriate. For other natural hazards some similar notional scale of severity affecting an area or site must be visualized. If a representative value \(EL_i/\text{SI}\) is to be chosen for each classification \(I\), the steps in the scale should not be too
large, although to make them too small will over-complicate the method.

Once an appropriate scale of intensity has been defined, expert opinion must be sought regarding the corresponding value $EL_i/SI$. Such matters as precise location (relative to the likely source or motion of the hazard), standard and type of construction or other nature of the properties insured will need to be taken into account. This is a very difficult task, which may require knowledge of several technical disciplines. As often happens with such problems, the range of values put forward for any particular set of circumstances by several experts with different training and experience may vary widely.

17.4 Evaluation of the $R_i$'s is by no means simple either. It is usual to suggest that use should be made of any available historical data on natural disasters which have occurred in the particular region. However, there is rarely a sufficient complete, detailed and credible record of past events available. As noted earlier, earthquake records in Japan from 1498 are used in rating. Four-hundred and eighty years may seem to be a very long period, but, for any one location, few large earthquakes will have affected it, even in such an active area. Therefore, it may be unwise to attach full credibility to any estimate of return periods for severe events, even based on such long past records. Also, there is no way of knowing whether the activity indicated over the available data period can be considered representative of levels of activity which may occur in any future period. Similar problems affect any data available for other hazards in other parts of the world. Sometimes, incomplete, and probably biased, records exist relating to severe events in history, but can hardly be considered reliable for calculations. For many areas, particularly outside Europe and Asia, there was no population to record events with any degree of completeness, if at all, until last century. Comprehensive data has, of course, become available for nearly all areas in recent decades as sophisticated measuring devices, communications systems and satellite monitoring have been introduced.

17.5 It is because of the difficulties discussed above that the loading factors $l_i$ and/or $L$ are introduced into the formula. If such factors are not included, it is feared that the premiums calculated may well prove to have been inadequate for the insurers. $l_i$'s could be regarded as safety factors to allow particularly for uncertainty in the assessments of the associated $EL_i$, $R_i$ factors. It may then be expected that
these factors would be larger for more severe, less frequent events. It is usually suggested that, whereas the basic calculation is attempting to find average expected costs, an overall fluctuation (or error of estimation) loading $L$ is required. Different schools of thought suggest that $L$ should be a fraction of the standard deviation or of the variance of the calculated values (although such measures must themselves be somewhat unreliable).

17.6 To carry out such detailed calculations for each individual policy would be extremely onerous. It introduces more elements of approximation to apply the principles to similar properties in a particular area, but doing this on a sensible basis may be considered comparable to normal collective rating procedures. Application of this type of calculation to a wider grouping of risks may remove some of the over-sophistication which such a complex method, based on unreliable data, introduces. The overall potential adequacy of premium income from a hazard territory might be assessed in this fashion.

17.7 Once the best efforts have been made to find mean values for $E L_1$ and $R_1$, and loadings then added for safety, it is probable that relatively high premium rates will result. It may be felt by policyholders and insurance supervisory authorities that these rates are unreasonably high.

17.8 Compared with the theoretical premiums calculated as above, the traditional methods of obtaining rates for covering natural hazards usually appear to give remarkably low values in many areas. It often seems that rates charged have been based mainly on the highest intensity of damage experienced in the area in the past (which may or may not be the highest intensity which may potentially occur) with estimated return periods for such events and estimated damage levels on current exposures from such an event, with only a small, arbitrary allowance for losses from less severe occurrences (which may nevertheless be considerable). Market forces have tended to erode premiums, particularly in areas where severe disasters have not been experienced recently. Discounts are sometimes given to so-called superior risks. However, the superiority is usually judged with respect to the basic policy cover, rather than the special peril cover, which may require somewhat different qualities, e.g. a very good fire risk may not necessarily be a good earthquake shock risk, and it may not even be a good earthquake fire risk since conditions following the shock will be rather different from normal.
17.9 Where special perils are included for standard cover under package policies, the allowance made in the composite premium is often unclear. Even if adequate allowance was originally made, there is a tendency for income from this source to become aggregated with normal basic risk premiums. By the nature of these catastrophe perils, the appropriate part of premiums received in years when no catastrophe losses occur should not be treated as profit, and should certainly not be used almost unthinkingly to reduce losses arising from inadequate basic premiums for other sections of cover. Various problems relating to building up catastrophe reserves will be discussed later.

17.10 Another important factor which it is difficult to incorporate into the theoretical method of premium calculation is the cost of reinsurance. Reinsurance is also discussed later, but it should be noted here that the insurer's premium income must be adequate to cover his retained losses, and expenses, and pay for his reinsurances. Depending on the distribution and type of the direct writer's account, his reinsurance premiums may greatly affect the rating levels which he must use in offering cover against catastrophe perils in some areas.

17.11 The discussion above has been concerned with the natural hazards. Similar problems arise in the rating of man-made hazards. In fact the difficulties are probably even greater in this area, as even less data on past losses are available and advancing technology is continually changing the nature of the risks. It has already been said that, where man creates a potential catastrophe situation, it is usual (and, hopefully, obligatory) for him to try to foresee all circumstances which might trigger such a disaster, and take all preventive measures possible to ensure that it can never happen. But, unforeseen events have occurred, and will continue to occur, leading to severe losses. It is surely a fruitless exercise to attempt any elaborate statistical analysis to fix premium rates in such conditions.

18. INEQUITIES AND STATE INTERVENTION

18.1 Even in the absence of full data, it seems obvious that some people and properties are more exposed to catastrophe hazards than others. If the premium calculation process gives full weight to the apparent relative hazard, an awkward situation arises. Those at low risk would be eligible for low premiums, but tend to consider any charge a waste of money as the peril is so unlikely. However, those at
high risk tend to feel that they are being overcharged. One reason being that, in order to live or work in high risk areas, it seems that people have to discount the level of hazard involved, until it is forcibly brought to their notice. It has often been observed that special-perils cover is generally sought at relatively low volume in a high risk area until after a disaster has occurred in a neighbouring area to bring the dangers alive, and trigger a shortlived period when cover is actively sought. Thus, rates tend to drift downwards until after a loss occurs, when some increases become possible. This means that insurers have difficulty trying to achieve a balanced portfolio with any continuity of exposure in each region. This instability in the business further complicates any attempts by the insurer to adopt proper rating and reserving principles for these types of cover. To use average damage levels and estimated return periods of more than a few years (sometimes up to, say, 200 years) on an account where the business changes annually is clearly unsatisfactory. The erratic cycle in premium rates and exposure also produces inequity between generations of policyholders, and between those in neighbouring areas exposed to similar risks.

18.2 When a catastrophe occurs, particularly in industrialized countries, some inequity in treatment sometimes results. Those who had chosen to pay for insurance are, of course, recompensed to some level by their insurer. However, if the disaster has been of sufficient magnitude, government funds are often made available to those who suffered. Even if the applications for relief are strictly supervised and benefit given in the form of low cost loans, those who deliberately chose not to purchase available insurance against the loss are frequently given unfairly generous treatment compared to their more prudent fellows. Where grants, rather than loans, are offered and insufficient official scrutiny allows some fraudulent claims, the inequity becomes even greater.

18.3 The private insurance industry by itself cannot deal with these problems. In order to preserve equity with other policyholders and protect solvency, where the risk of catastrophe is high, insurers have to charge high premiums, or may have to restrict their acceptances, offer limited cover with deductibles or on a coinsurance basis, or even refuse to offer any cover if the risks are too great. Where different levels of exposure are not too far apart, some closing to the average in the rating for a territory may be justified, but this could lead to adverse selection. When indicated high-risk rates are too high
for the potential policyholders to afford or no cover is available, it seems that the only courses open are for them to stand the losses as they occur (if they cannot remove from the exposed area), or for state intervention to ensure that some form of subsidized insurance cover is provided.

18.4 For a government scheme to operate successfully it seems to be essential that cover is compulsory, and special land use and construction codes are introduced and strictly enforced. Most existing schemes involve the private insurance market as the direct writers of cover. The New Zealand scheme has been described earlier. A flat rate unsubsidized premium is chargeable partly because all unusual hazards are covered, equalizing the various exposure levels substantially. It has been suggested that a similar federal all-risks scheme for the whole of the U.S.A. could have substantially smoothed exposure levels, as most places are vulnerable to some degree to one or other of the natural hazards. At present though, most schemes protect small areas against single perils. Strict regulations are imposed to prevent irresponsible development and limit the extent of very high exposures, but thereafter access to insurance is guaranteed. Where insurers are reluctant to grant cover, or the premiums required are very high, industry pools may be formed and the state may pay a premium subsidy and/or provide excess of loss or stop-loss reinsurance in respect of the catastrophe peril. Note that these U.S. schemes only make catastrophe cover available. It increases capacity problems to make such cover a compulsory part of appropriate basic insurances, but also gives a maximum spread of risk and reduces selection. Such automatic mandatory cover is usually considered most appropriate only to domestic or small private business risks, as these are likely to be most vulnerable and in most social need of benefit from a special scheme.

The aggregate losses under such schemes could be very high, depending on area affected and seriousness of the disaster. Losses and expenses can be reduced, and funds saved for really serious catastrophes, by imposing deductibles or franchises. This obviously reduces the social benefit from the existence of the scheme, but may be the only way that premiums and subsidies can be kept to economically viable levels, and/or sufficient capacity can be offered by the insurance market and the reinsurers. When the state decides to act as a reinsurer, it must weigh up the economic effects on the country’s finances of the occurrence of the peril insured against. Although it
may seem to be expensive in foreign exchange terms to obtain reinsurance of a state assisted-scheme from foreign professional reinsurers, greater ultimate security may result. A really severe hurricane or earthquake could destroy so much property in a vital area of a country that its economy is seriously disrupted for many years. If the assets held by local insurers, and the state as reinsurer, are impaired by the disaster most of the benefits from the existence of the scheme may be lost. There is some further discussion of points related to this aspect later.

19. ACCEPTANCE LEVELS AND RETENTION LEVELS

19.1 Any insurer who writes catastrophe business must carefully consider the level of his capacity to withstand losses. To avoid building up concentrations of risks in target areas, it is prudent to consider applying limits to the volume of business which will be accepted for catastrophe cover in those areas. However, to do this frequently conflicts with normal business interests, because turning away potential insureds who require catastrophe cover means turning away any ordinary insurances which they would also have placed. Although zonal acceptance limits are still necessary, protection can also be sought by reinsurance. Because of the very unbalanced nature of catastrophe experience, it is rare for stop-loss reinsurances to be available at acceptable terms in the general market, although some covers may be arranged in special circumstances. The more usual protection is an excess of loss catastrophe reinsurance, under which the reinsurers will pay $X\%$ of the reinsured's aggregate loss between amounts $Y$ and $Z$, incurred within any period of $h$ consecutive hours ($h$ is usually 24 or 72) within the period of reinsurance (usually one year) arising from the occurrence of one of the specified hazards. $X$ is usually between 80 and 100 so that the insurer obtains substantial cover, but also retains a direct interest in the layer of losses covered, and so has greater incentive to maintain a suitable acceptance policy regarding both underwriting standards and zonal limits. In deciding on retention levels, the insurer should consider the possibility of more than one disaster occurring in the year. A reinstatement clause is often available under a reinsurance arrangement whereby, if the layer of cover is exhausted (or partly exhausted) by one event, a similar replacement layer (or part layer) for the remaining contract period will be automatically offered on payment of an agreed reinstatement premium.
19.2 As indicated earlier in discussing what constitutes a catastrophe, the size of the insurer, and the type and mix of business written, will be vital in deciding appropriate retention levels. One definition of a catastrophic loss is a loss which financially affects the net worth, or imbalances the flow of net income, to an unacceptable degree. It has been suggested that catastrophe retentions should be related to various measures such as net worth, shareholders assets, invested assets, earned premiums or expected claims. Further considerations are the likely extent of ‘normal’ fluctuations in underwriting results and fluctuations in the value of the invested assets.

Most reinsurance agreements are negotiated in respect of separate classes of business. When deciding on the limit for retained losses in any one account, some consideration should also be given to the losses which might arise in other accounts should a catastrophe occur. Obviously, it is the total of all losses from all classes of business (including any inwards reinsurances), after reinsurance recoveries, that must be within the maximum amount that the company feels it can stand to lose on the occurrence of a single catastrophe.

19.3 To assist in formulation of suitable policy towards zonal limits, retention limits and reserving levels, several computer simulation models have been constructed. Dr. Friedman describes a project of this type in his paper “Insurance and the Natural Hazards”. The hazard area of interest is divided by a grid system. For each subdivision, local conditions relevant to the peril (e.g. geological data for earthquake hazard) must be programmed, together with details of the properties exposed to the peril. Although data is not available to predict the location of future events, simulations of the results of events of selected size at selected locations or following selected courses (depending on the type of peril) can be produced.

Some recent ‘as if’ simulations have estimated that

(i) if an earthquake similar to that of 1906 were to hit the San Francisco area now, a property loss of over $50 billion with 20,000 deaths could result; and

(ii) if a hurricane similar in size to, and course followed by, Betsy occurred now the damage could be about $10 billion.

No doubt even more horrendous losses in terms of property damaged and lives lost could be estimated for other events in other strategic areas, for example Tokyo Bay.

19.4 In view of these aggregations, the need for zonal limits to
acceptances should not require further emphasis. However, some doubts have been expressed as to whether relaxations in underwriting conditions and increases in zonal limits made by some insurers in such target areas in recent years have been the results of genuine reassessments of the dangers, and increased capacity, or merely reflections of outside economic and business pressures.

20. PROBLEMS OF REINSURERS

20.1 In seeking reinsurance, an insurer must exercise normal care. Professional skill, experience and a strong financial base are obvious requirements. Particularly for relatively wide or high layers, many co-reinsurers may participate in one agreement. Reinsurers will also seek to protect their own accounts by placing outward retrocessions. Thus major risks get spread widely through the worldwide reinsurance markets.

20.2 The difficulties of direct writers in attempting to restrict concentrations of risk in vulnerable areas, and in assessing suitable premium rates for catastrophe perils have already been discussed. Reinsurers face even greater problems in relation to the catastrophe covers they provide. It has become standard practice in recent years to require the reinsurer to fill in a questionnaire indicating estimated sums exposed to various perils in particular target areas. Some more detailed questions may be asked in certain circumstances. Obviously, the information provided must be of limited detail, and so can be only of limited use. Where direct insurers find it extremely difficult to estimate the possible extent of their own total losses from the data available to them, it is virtually impossible for a reinsurer to build up a fully credible picture of his possible losses from a serious event when he is at arms length from the underlying exposure data. Where retrocessions are involved, data will naturally tend to be even less credible. Most reinsurers can only expect to discover the true extent of their ultimate exposure in many areas after a claim event has occurred, because of the complexity of the reinsurance market itself.

20.3 Whatever method of rating is employed, there is usually some implicit assumption that there will be continuity of business placed. The nature of high-layer excess of loss catastrophe cover is such that wild fluctuation of premium rates would result if such continuity did not exist. Even so, it has been suggested that there can really only be a smoothing of losses over a period, because, if a major disaster does
occur, the market will almost certainly have to increase rates to rebuild its financial position.

20.4 Another problem suffered by reinsurers is that of delay in notification of losses. This arises to varying degrees with all their business, but can be particularly serious when a catastrophe has occurred. Some data suggests that following recent serious hurricanes in the U.S.A., only about 60–80% of ultimate losses had been notified to major reinsurers after 3 months, rising to 85–95% after 6 months. Since the hurricane season in the U.S.A. is principally August and September, it is very difficult for a reinsurer to establish a valid estimate of IBNR claims at the end of years in which hurricanes have occurred. Presumably similar (or worse) slow reporting would apply to losses from other hazards and in other areas. Where retrocessions have been accepted, notifications of claims under those will necessarily be much slower.

21. RESERVES

21.1 In view of the long return periods for major catastrophic events, it is clear that the normal yearly basis of accounting is inadequate for this type of business, unless special provision is made for the infrequent, very large, losses by the creation and maintenance of catastrophe reserves. If the writing of catastrophe business is regarded as a continuing venture, despite the issue of annual policies and consequent turnover in portfolio, it is vital that a suitable proportion of premiums received in respect of that business, particularly in years when no serious loss events have occurred, is not immediately regarded as profit available for distribution to shareholders, or for other purposes.

21.2 At present, in almost all countries, transfers to catastrophe reserves are treated as non-revenue items for taxation purposes, and so can only be made from retained profits after tax. The justification for this treatment is that statutory accounting principles require each period of business to be presented and stand on its own. No consideration can be given to future business that may be written. It can be argued that, unless a catastrophe has already occurred, no losses can yet have been incurred, and that any future catastrophes must be considered only as contingencies which cannot be predictable or quantifiable, and so cannot be recognized as specific existing liabilities.
This practice tends to discourage specific reserving, and submerge any provision made for future disasters within ordinary 'free' reserves. This adds complexity to assessment of relative solvency and security offered by companies writing differing mixes of business.

21.3 If transfers to catastrophe reserves were to be made tax deductible, various safeguards would have to be introduced, otherwise there would be scope for some companies to use them as a device for manipulating earnings, hiding undisclosed profits and avoiding tax. If such reserving were properly regulated, the eventual tax payments over a long period should be little changed, with only an element of deferment, since disaster losses are, of course, already fully deductible once they have been incurred. It would be necessary first to agree a workable definition of catastrophe, since restrictions would have to be placed on the eligibility of payments out of the reserve. From earlier discussions in this paper, the difficulties involved in obtaining a single definition appropriate to the entire insurance market in any territory will be appreciated. Similarly some restrictions on the size of annual transfers, and on the balances maintained in the reserve would be necessary. Where specific catastrophe premiums are payable, a fixed percentage might be considered eligible for transfer to reserves. Where they form part of a composite premium, the allowable portion could be difficult to establish. Clearly upper and lower limits to the size of fund allowed would then be necessary. An alternative approach would lay down a method for calculating the size of reserve required, making the amount of transfer merely an adjustment figure. Since exposures and expected losses, after adjustment for reinsurances, are so difficult to compile and assess, even for one type of hazard in one territory, it could be almost impossible to set out a standard formula to be applicable for companies operating in many hazard areas. Also, since catastrophes of different sorts in different regions may be considered to occur independently, several serious events might occur within the same accounting period. A negative reserve could obviously not be allowed. However, the justification for holding a reserve at all is to provide for adverse experience, and so it should not be unreasonable to allow for a certain amount of fluctuation in the balance reserved, rather than requiring it to be related to continuing exposure levels.

21.4 Despite the tax position, most companies calculate an amount which should be regarded notionally as in reserve for catastrophes, for internal management purposes. Some companies even
designate a part of their free reserves as shown in their published accounts as being a catastrophe reserve. Computer simulations of expected losses, by programming current sums insured in each at risk area, applicable sets of expected loss levels EL₁/Sl and return periods R₁ for intensities of event I in each area, and generating random numbers to simulate the occurrence of events and the associated losses over long periods, have been suggested for use in deciding on appropriate levels for these notional reserves. Alternatively, a simplified calculation, involving adjusting past gross losses from catastrophe type events to allow for inflation, changing portfolio exposures and reinsurance arrangements, and then averaging over 10 or 20 years may be used to obtain estimates of annual transfer amounts.

21.5 Whether catastrophe reserves are set up before or after tax, designated in the accounts or notionally held, some special consideration should be given to the most appropriate investments for the amounts involved. In the event of a major disaster occurring, a large portion of the reserve may have to be made available at relatively short notice, although immediate liquidity of the full amount required is unlikely to be necessary. For insurers writing catastrophe business in more than one country, it will not be known, until after the event, in which currency payments must be made. This means that, in addition to satisfying basic domestic and foreign reserving regulations and tax requirements, special account must be taken of foreign exchange regulations and restrictions. Although some matching of currencies may be desirable, certain drawbacks to this course of action exist. Many vulnerable areas lie in countries with strong economies offering wide opportunities for investment not dependent solely on activities in individual ‘at risk’ regions. However, other vulnerable areas lie in small countries where a disaster in a critical location could seriously impair the value of any local assets. It would usually be impossible to achieve full currency matching anyway, because of the limited size of reserves compared to total catastrophe exposures covered. Apart from these problems, the usual investment considerations will apply. Thus, the desire for income to be maximized must be balanced against the need for security and, particularly as the date of the next catastrophe event cannot be predicted, limitation of asset value fluctuation.

22. FUTURE DEVELOPMENTS

22.1 The rapidly increasing technical expertise in many special-
isms required to attempt proper assessment of increasing numbers of man-made risks has already been commented upon. Rather than individual insurers needing to employ experts in all fields, either as staff members or consultants, the most logical development will be for greater market co-operation in the setting up and staffing of technical bureaux.

22.2 Great problems of lack of capacity are caused by the huge liabilities which might arise from a man-made catastrophe. At present this problem has been partly solved, as noted in earlier sections, by national and international legislation to limit the total amount of liability which can be attached to any single incident. Already it is being suggested in some quarters that these limits would not be high enough to give adequate compensation following serious events, and so are inequitable and unjustifiable. As man builds more and bigger potential disaster situations, can any improved system for compensation be created?

22.3 A lot of research into the causes of natural catastrophes, prediction of their occurrences, and possible measures to alleviate them is currently being carried out around the world. Many insurers are actively promoting research in these fields.

By the increased use of geological surveys, and detailed measurements of minute movements of the earth’s surface and underground pressures and temperatures within rock structures, etc., a greater understanding of the mechanism of earthquakes and volcanic eruptions is being built up. Similar investigations of winds and cloud formation, development of storms, etc., are being carried out. Short term prediction of some potential catastrophes, such as an impending hurricane, can be made confidently on occasions for some areas. Unfortunately, this is not possible in all areas of the world, or for many types of hazard. Any sort of warning could be valuable in reducing losses of life and property, as many movable articles might be removed from the at risk area or placed in relatively protected positions, and many measures taken to protect even fixed property from some hazards. Further research into development of improved methods of construction and design, greater supervision to ensure that existing building codes and other regulations are properly observed, and the introduction of new codes and legislation over wider areas will also help to reduce further losses.

22.4 Two developments, which are unlikely to occur in the near future, in the field of active research of natural catastrophes could
cause problems for insurers. If long term, accurate prediction of catastrophes can eventually be made, presumably elaborate disaster plans could be put into operation to protect lives and movable property. But, although some land use restrictions and building codes can reduce damage to fixed property, prediction of a catastrophe affecting an area could not eliminate losses. How would insurers then regard catastrophe hazards, particularly in relation to cover for fixed property? Perhaps state schemes would have to take over responsibility. Perhaps long term insurances for these risks would have to be provided, on the lines of life policies, with a 'medical' report on current hazard exposure situation before acceptance!

Other research is directed not at prediction, but at elimination or reduction in severity of the hazard. It is suggested that major earthquakes might be averted by the triggering of small tremors to slowly release any pressures which build up in the rock, and hurricanes might be prevented by chemical dispersal of developing atmospheric formations. If successful, these measures would be of great benefit. Depending on the costs involved in carrying out these measures, it is possible that such projects could prove of particular benefit to the poorest countries of the world. In such areas at present, the inhabitants have no opportunity to move out of the way of natural (or man-made) hazards, but cannot afford to purchase insurance cover, and cannot be given any cover by their governments, partly because of the burden of past disasters. If such projects could reduce wastage of resources resulting from natural hazards in developed regions of the world, the financial benefits are obvious. This would be an optimistic note on which to close, but what if miscalculation results in the triggering of a new combination of natural-and-man-made disaster? Would the agency carrying out the operation have sufficient funds to compensate for damages caused, or would special schemes of insurance have to be created?

23. BIBLIOGRAPHY

23.1 A complete bibliography to cover all the topics discussed in this paper cannot reasonably be provided here. Numerous publications are produced regularly by the various technical bodies associated with the types of hazards discussed, and by those doing research into these hazards. Papers relating particularly to catastrophe insurances are also produced by such bodies as the Reinsur-
ance Offices Association and by large insurance and reinsurance companies around the world. Also occasional articles appear in the insurance press on catastrophe risks.

23.2 Titles of selected relevant articles in recent actuarial publications are given below:


FRIEDMAN D. G. 'Insurance and the Natural Hazards' *ASTIN*, VII, 4.


Report by the Catastrophe Study Group to the General Insurance Seminar 1975. Various contributions in GIRO bulletins, particularly Nos. 21 and 22.