Some Considerations of Major Non-Nuclear Hazards

by F.R. Farmer

There has been an upsurge of interest in risk comparison in recent times In commenting on some risk studies, on the energy scene and on types of risk, I will first discuss risk in the non-nuclear energy industry and then expand onto a wider recognition of risk in an industrial society.

The objective of these risk studies, in my opinion, is to verify that nuclear power is safer than most alternatives and that the so-called "soft" options have a very hard core. Inhaber Ref. [1] has particularly drawn attention to this by including the risks in the construction programmes for various energy options and in the manufacture and transport of steel and other materials used in them.

Two comments can be made on this matter. First, it is likely that nuclear power is safe based on short-term issues; the imponderables that carry weight with the objectors are the uncertainties of major accidents, long-term wastes and proliferation. Current risk studies do not banish these fears. Secondly, if these studies aim to influence choice of energy mix for the future, they should extrapolate data to the period 2000/2050 and not use present comparisons. This will be illustrated later.

Although the energy scene is very wide, some authors only compare electricity producers; others, such as Inhaber, take a broader view and consider the steel, concrete, aluminium and chemicals that various energy programmes will need. In the United Kingdom and many other contries, transport takes an important slice of total energy, about 30% as heat supplied to final users. To provide this in the future, there will be major industries producing, processing or handling liquid or other fuels, with associated chemical plants. If biomass is used on a large scale, there will be a need for nutrients and hence large plants extracting nitrogen, oxygen, producing ammonia, etc. This is not unlike the site at Canvey Island where the risks have been studied and reported Ref. [2], a point I will return to later.

Hence the future energy scene will include mines, quarries, steel and other metals, chemicals and plastics with their associated storage and transport.

TYPES OF RISK

The risks in any programme are of many types:

1. Immediate death or injury.
2. Delayed effects, of relatively high probability.

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3. Risks to the public which are protracted and of low probability per person.
4 Risks from major accidents.
5 Risks to the environment.

(1) All the studies I have seen quote figures for present industrial fatality rates. Later, it will be shown how mining fatalities have fallen off and I predict that by the year 2000 the rate will be within a factor of two of most industrial accident rates, and will not dominate the choice

(2) Pneumoconiosis has been the major long-term high-risk delayed effect of mining. In the United Kingdom, about 450 deaths occurred as a result in 1974, but now it is unusual to see any evidence of pneumoconiosis in men who have been exposed to dust for less than 20 years.

(3) The incidence of low probability effects on the public due to air contamination varies by at least two orders of magnitude. So little is known of the long-term effects of chemicals at low concentrations that the selection of any figure can be disputed.

Additionally, I am loth to give any great weight to numbers which are derived by multiplying low risks by large populations, such as a risk in the range 10^{-3} to 10^{-4} per person by 10^6 to 10^7 people. We are all at risk of accidental death of about 10^{-2} per person. Most long-term effects from food, habits, environment and other factors with short-term effects, are extremely difficult to study and measure and no great weight can be put on comparisons now made.

(4) The risk of major accidents is a recent interest, as in WASH-1400 Ref. [3] or more recently from the study of Canvey Island Ref. [2] Although we have yet to come to terms with societal risk, one thing is clear the chance of an accident killing 10 000 people at 10^{-5} per year is not equivalent to the death of one person every 10 years Indeed, it is this catastrophic event which appeared on the scene when studying theoretical accidents to nuclear power stations that is now seen to have a parallel in the petrochemical industry.

(5) Finally, can we balance the long-term environmental effects of an energy programme? I think not. We are only at the beginning of some studies, such as the effects of CO_2 on the atmosphere, temperature effects at low level on the micro-climate, the effect of deforestation. Indeed, we are barely aware of the problems of maintaining $5 - 10 \times 10^9$ people on this planet

RISK IN A BROADER CONTEXT

I would now wish to consider risks in a wider context, and not solely in relation to a nuclear programme. Many studies are carried out to assess the attitudes of different groups of people to accidents or unpleasant events and to give marks or ratings to their opinions One objection that is often raised to atomic energy is the risk of cancer. The issue becomes emotive, and adverse opinions, once formed, seem not to be changed by additional information

Many chemicals are carcinogenic and, according to Sir Edward Pochin Ref. [4] some occupations may carry a risk of cancer to workers up to 30 times higher than employment in industries involving radiation exposure. Even so, the chance of developing cancer by exposure to chemicals in industry is said to be very low.

A Study Group Report of the Royal Society Ref [5] says:

"Many specific hazards of cancer had been traced to occupational exposure to chemicals in industry, though such hazards were not likely to account for more than about 1% of all cancers now occurring in the UK"

The chance of dying from cancer from so-called natural causes is over 20%, i e 1 in 5 in the UK and amounting to 100 000 per year, but according to the Royal Society report

"A high proportion of all cancers, perhaps 80%, were thought to be environmentally determined, in the sense that, given different environments, the incidence of most types of cancer would vary"

I have found it difficult to obtain consistent meaningful figures on risks; one set of data appears in the Canvey Island Report Ref. [2], viz .

Table 1. Main Types of Fatal Accidents in Great Britain

	Number of fatalities	Chance of the average individual being killed
Motor vehicle accidents	7 219	1 3 chances in 10 000/yr*
Accidents in the home	6 717	1.2 chances in 10 000/yr*
Accidents at work	753	0.3 chances in 10 000/yr**
Others	3 646	0.6 chances in 10 000/yr*
TOTAL	18 335	

* Averaged over the total population of Great Britain
** Averaged over 22 million employees

The report draws attention to the fact that motor vehicle risks are not equally shared, it is much higher for young males between 18 and 25 The risk from accidents at home is highest for the very young and those over 65, these groups carry 70% of the risk If we consider those at work under the age of 65, the average fatal accident rate from all causes is 2 7 in 10 000 per year. It is interesting to compare this with the chance of death from natural causes by age group:

Table 2. Risk of Death from Natural Causes by Age Group

Age	Risk of death
From 5–14	1.9 in 10 000 per year
15–24	3.0 in 10 000 per year
25–34	4.8 in 10 000 per year
35–44	16.2 in 10 000 per year
45–54	55.0 in 10 000 per year

It can be seen in Table 1 that accidental death at work is only a small proportion of all accidental deaths, about 4% Even so, accidents at work are taken very seriously, both for death or injury, and analysed with respect to age, sex, industry, etc , and reported in various ways Ref [6]

An analysis of the age dependence of fatal accidents at work appears in Sir Edward Pochin's report to the ICRP Ref. [4]. For manufacturing industries and construction, he concludes that in both groups the age at accidental death is slightly, but significantly greater than that of the exposed population. This is apparently due to the fact that the fatality rate (per year per million employed) rises until the age of about 30 in manufacturing industries, and until about 20–25 in constructional work, and then remains approximately constant with age until 65 or over There is a significant difference in the average fatality rate between construction and manufacturing industries – as indeed between different industries. Pochin quotes that for 1971 the average in manufacturing industries was 0.4 per 10 000 per year, whereas for construction it was 1 5 per 10 000 per year These should be seen against the number in Table 1 of 0.3 per 10 000 per year for all fatal accidents at work shared by 22 million workers.

If we are using these studies to consider future options, then we should extrapolate past and present data to the future. Briefly, the relatively dangerous industries have ample opportunity to reduce risks, this is not so easy in the relatively safe industries. Coal mining gives a good example of this. The Chief Safety Engineer of the National Coal Board in Britain Ref. [7] quotes annual average fatalities per 1000 employees over 10 year periods from which I extract the following data, suitably scaled for 10 000 employees, to compare with Tables 1 and 2.

Average fatalities per 10 000 employees	During time period
31 4	ending 1872
7.3	ending 1952
3 0 (approx)	ending 1972
2 2	for the year 1972

Hence projecting beyond the year 2000, I would expect the rate to fall to 1 0 or lower

Apart from the specific interest in safety at work, there seems also to be a growing public awareness of new hazards, or of a steady growth of hazard in an industrial community. Why?

There are many contributing factors.

1 Accidents have always happened, but now we hear about them wherever they occur. Aberfan, Flixborough, Seveso, Los Alfaques (the Spanish camp site)

2 New or frightening consequences come to light thalidomide, dioxin (Seveso), or radiation

3 The contrast between the healthier, safer life of today as compared with the last century is now seemingly threatened by the growth of supertechnology. This was referred to in the first report of the Advisory Committee on Major Hazards Ref [8] as follows

"Although many mistakes have been made in small scale manufacturing operations, they have usually had limited consequences The pressures for greater efficiency have led to the growth of capital intensive new plants (for example, the capacity of some hydrocarbon processing units has increased tenfold in the last 20 years), increases in size of many traditional plants, the grouping of associated processes in one area, and the difficulty of isolating them from centres of population This has brought about a very significant increase in the number of people, whether employees or members of the public at large who could be endangered at any one time should anything go wrong Because of their present day size and throughput, there are now many plants throughout the world where a critical first mistake can result in disaster"

We see some response to this effect in the request for the study of the safety of the many installations on Canvey Island Ref [2] and the concern of local Authorities which led to a study by the Health & Safety Executive of the risks which would be associated with pipelines from St Fergus in the Grampian Region in Scotland Ref. [9].

Canvey Island is a highly industrialized area of about 50 km^2 on the north Thames shore, east of London There are oil refineries, a methane terminal, ammonium nitrate production, and an LPG (liquid propane gas) cylinder filling plant

The report is an assessment of the hazard arising from these activities The hazard to an adjacent population of over 30 000 could arise from releases of ammonia, hydrofluoric acid, or from fire or explosions of LNG (liquid natural gas), LPG or inflammable liquids. The report is issued by the Health & Safety Executive and gives the assessed individual risk at various locations and the societal risk – the risk that many people might be killed at one time. This is what the Executive said about the method of assessment

"The assessment of risk in a complex situation is difficult No method is perfect, all have limitations of one sort or another We agreed wtih the investigating team that the quantitative approach was the most meaningful way of comparing different risks The team should attempt to quantify the probability of various types of accidents that might occur, and then the probability of a whole range of possible consequences This would enable the risks to be described not simply as "large", or "small", but in a quantified, numerical way To describe the probability of killing 100 people as a result of one type of accident as 1 in 10 000 compared to 1 in 100 as a result of another type of accident, is much more meaningful than saying the chances of these types of accident occurring are "very remote" or "quite high" To express risks in numerical terms provides one with a common denominator, a method of putting various risks in perspective and comparing them with each other "

The study indicated that individual risk ranged from 2 to 13 per 10 000 per year, depending on location Societal risk was determined to be about 20 per 10 000 per year (for 1000 fatalities or more) and about 2 per 10 000 per year (for 10 000 fatalities or more)

Recommendations were made which, if implemented, should reduce the risks in all categories by about a factor of two.

Whereas these two studies were carried out by, or on behalf of, the Health & Safety Executive, it is clear that similar studies will be required in the future to be carried out by those handling, processing or storing large quantities of potentially hazardous material.

The consultative document of the Health & Safety Commission Ref [10] sets out quantities of various materials for which notification would be required, on premises where there are specified substances in quantities ten times the notifiable level, a hazard survey would be required

The requirement to carry out a hazard survey and the skill to do so, has been growing in a number of industries, in particular in the nuclear, aircraft and aero-space industries. Some good work has been done in the chemical and pharmaceutical industries but the practice is not yet widely based nor, in general, developed in depth as might be appropriate to installations of exceptional risk

The Health & Safety Consultative Document suggests particulars to be included in a hazard survey report and gives guidance notes. No doubt there will be many discussions about the contents or these reports; there can be no simple answer

A hazard assessment is not, however, a numbers game. This expression has often been used to denigrate quantitative assessments by those who prefer to use their judgement and imply that others do not Quantitative assessment of risk is here to stay, but is to be used when information is available — or can be found — and is relevant Sir Kenneth Berril Ref [11] expressed my views as:

"You will not get away in a document — as you would 20 years ago — with material that's purely descriptive While there remains a wide bracket of doubt, the attempt to be quantitative is much greater than in the past and it is going on all the time And not only in the Treasury but in, for instance, the Department of the Environment — to decibelise the assessment of noise say — the attempt to predict accurately, to be quantitative, is pressed And the essential process — boiling down vast quantities of data to something manageable — is scientific I call it scientific I am absolutely unrepentant — I call it damn hard science!"

A hazard assessment does not require the study of all accident modes occurring in all possible ways under all possible external conditions This would be impossible, unnecessary and indigestible A selection is required and may be the subject of some debate but the product should be clear and meaningful

A hazard assessment should not, in general, aim to describe the worst or maximum credible accident There is seldom a worst consequence as more and more imagination can be applied to the scene-setting calling for events or coincidence of lower and lower probability On the other hand, the assessment should not deal only with events of high probability thought likely to occur — or which could occur within the next ten years The degree of improbability assumed should be related, where possible, to the severity of the consequences.

Although the form of presentation of a hazard assessment may vary, I am certain that for most complex sites the hazard cannot be expressed as a single parameter. There is inevitably a range of possibilities for the way in which accidents can occur and can develop, which leads to a wide spectrum of possible end results. Several attempts have been made to correlate the results of past accidents to derive an average index. V C Marshall's review Ref [12] of explosive accidents (gas, liquid, solid) derives an index of fatalities per tonne which is around 0 5 to 1 0 in the accident range of 10–40 tonnes This covers many accidents. His index decreases with size of accident. Although this average is useful, it is generally agreed that the end result may vary by at least one or two orders of magnitude Some of the variability will be due to site conditions, weather patterns, population distribution and time of day and some of these factors will have probabilities associated with them which are available or can be determined.

The report of the Advisory Committee on Major Hazards, the Health & Safety Consultative Document, and my remarks about hazard assessment, all refer to hazards which result from single major accidents and do not bear on the problem of the hazards from the long-term exposure to dangerous substances. This is a very different matter. The Royal Society (UK) set up a study group on Long-Term Toxic Effects Ref. [5] to review current knowledge of the toxic effects on man and other organisms of long-term exposure to substances in the environment at levels not adverse in the short term. Their conclusions are interesting and I quote from the report:

"(i) Toxicology is not adequately supported as an academic discipline, it is swamped by routine tests of limited value and governed by regulations rather than by rational thought Great efforts are made in 'toxicity testing' of new chemicals and drugs, with expenditure in the region of £50 million per annum in the UK alone This activity tends, however, to be diverted into a sterile routine of exposure of many animals, without attention to mechanisms Only if mechanisms are understood is it possible to extrapolate toxicity measurements across species and from the large doses used in experimental animals to the exposures experienced by man, commonly a thousand-fold smaller

(ii) Nutritional and other variables that alter susceptibility to toxic effects by an order of magnitude or more are poorly understood and little studied

(iii) A major cause for concern is the production of cancer by industrial products As yet we have only a very crude idea whether a chemical found to be carcinogenic in a particular model system would prove a real risk in practice It seems unlikely that any group of current tests will provide a quantitative measure of carcinogenic risk to man, valid over different classes of chemicals. New tests for mutagenesis promise to be of value, but their results need to be validated by laboratory experiments on whole animals and correlated quantitatively with human experience

(iv) Systems for monitoring trends in human disease are inadequately developed The Office of Population Censuses and Surveys (OPCS) provides better data than are obtainable in most countries, but these are for the most part limited to mortality There is little information about the prevalence of ill health that is not lethal, so that it is extremely difficult to find out whether, for example, environmental noise causes an increase in mental illness To answer such questions, special surveys have to be carried out The possibility should be considered of extending the work of the OPCS to include regular monitoring or aspects of health that are not directly reflected in mortality rates Such monitoring could usefully include biochemical measurements, for example, of haemoglobin or cholesterol as has been done in the USA The OPCS should be strengthened so that it can improve the current systems of cancer registration and the notification of congenital anomalies

(v) Improved systems are required for monitoring the health of industrial workers exposed to new chemicals. Knowledge of the toxic effects of chemicals does not have a sufficient theoretical base to rely on extrapolation from the results of experiments on animals — a conclusion that is reinforced by experience with new drugs

(vi) The detection and measurement of risks in man would be facilitated if provision were made for the linking of the records of exposure to industrial and other hazards with hospital discharge and mortality data"

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