PLANNING GUIDE FOR NUCLEAR REACTOR ACCIDENTS

Description of Reactors

A nuclear reactor is a structure in which a fission chain reaction can be maintained and controlled. The nuclear fuel which drives the chain reaction is usually the U235 isotope of uranium. Natural uranium is a mixture of this isotope and the more abundant isotope U238 in the ratio of 0.71% U235 to 99.28% U238. The basic event is the splitting or fission of the U235 atoms by neutrons into two new atoms (fission products) as follows:

$$\text{U235} + \text{neutron} \xrightarrow[\text{fission}]{} 2 \text{ fission product atoms} + 2.43 \text{ neutrons (average)} + \text{heat.}$$

2. The neutrons produced when a U235 splits are released at high speed. In most reactors, called thermal reactors, these neutrons are slowed down to enable them to cause fissioning in further U235 atoms. This is accomplished by having uranium fuel surrounded by a moderator which slows the neutrons down. Moderators are light water, heavy water and graphite.

3. Reactors are characterised by the following three states:

a. Critical. When one neutron from each fission is available (after leakage and absorption) to cause fission in an adjacent U235 atom, there is a self-containing chain reaction and the mass of fuel is called a critical mass. The neutron population remains constant and there is a steady rate of heat production.

b. Supercritical. When more than one neutron is available from each fission to cause fission in adjacent U235 atoms, there is a multiplication of the neutron population and the heat generation rate increases. The degree of multiplication is called excess reactivity. This is characteristic of reactors during increasing power.

c. Subcritical. When less than one neutron is available from each fission to cause fission in adjacent U235 the chain reaction will not be continued and the heat generation rate will fall. This is characteristic of reactors in the shut-down state.

4. The three states are attained in all thermal reactors by suitable action of the control system. This consists of materials which readily absorb neutrons and which can be moved in and out of the core to achieve whichever of the three states is required.

5. The heat generated by fission in the uranium fuel is removed by a coolant, usually water. In power reactors the water coolant is at high pressure and temperature and is used to generate steam in a second circuit which contains the turbo-generator. In research reactors the water coolant rejects its heat to atmosphere.

Reactor Accidents

6. Nuclear explosions are impossible in reactors. The major accident of concern would be a melt-down of the fuel due to a loss of coolant, say from a fractured coolant pipe. If this happens, and the chances have been estimated at less than once in ten thousand years per reactor, radioactive fission product, of which radioactive iodine is of most concern, would escape from the fuel. For this reason reactors are constructed inside steel or concrete buildings designed to the highest standards of leak-tightness in order to contain such radioactive material and prevent it escaping into the air.

7. However, the accident would also cause an over-pressure inside the containment building since it would bottle up all the escaping energy from the reactor core. Since no man-made structure can be 100% leak tight, there will be a slow leakage of radioactivity from the containment under the driving force of this over-pressure. Hence the accident is characterised by a slow leakage of radioactivity (about 1% of the contents of the containment) over several hours, commencing, say, within about half to one hour of the melt-down.

8. Emergency response planning is based upon this accident scenario. Planners can think in terms of hours rather than minutes to effect remedial measures. However, the extent of the hazard will be dependent upon the size of reactors: the risk from small research reactors, such as HIFAR, will be less than a hundred times lower than a large power plant.

9. The major objective of emergency planning is to reduce the exposure of members of the public from the radioactivity leaking out from the containment. There are two exposure pathways, from the airborne plume and an ingestion pathway.

Plume Exposure Pathway

10. The principal exposure sources from the airborne plume of radioactivity would be:

a. whole body exposure to gamma radiation from both the plume and deposited material, and

b. inhalation exposure from the passing radiation plume.

The duration could range over many hours. The boundaries for protective action would be determined by prevailing weather conditions. In general, the objective of counter-measures would be to keep exposures below the National Health and Medical Research Council's recommendation "Emergency Reference Levels for Major Radiation Accidents".

Ingestion Exposure Pathway

11. The principal exposure from this pathway would be from ingestion of contaminated water or food such as milk, fresh vegetables or aquatic foodstuffs. The duration of potential exposure might extend over days to weeks but is unlikely to present a need for urgent counter-measures. Counter-measures are mainly concerned with food chain monitoring to ensure compliance with health standards.

Emergency Planning Zones (EPZ)

12. For guidance to planners, the following ranges and durations are typical of current world practice.

Accident Phase	EPZ Radius	Duration of Major Release
Airborne Plume Exposure pathway	1.6 km for research reactors, up to about 30 MW thermal; 16 km for large power reactors.	up to 1 day for all reactors.
Ingestion pathway	16 km for research reactors; 80 km for large power reactors.	Several days to weeks.

ATTACHMENT 2
TO APPENDIX 2
TO ANNEX D

SAFETY GOALS FOR NUCLEAR REACTOR PLANTS

The United States Nuclear Regulatory Commission (NRC) has recently proposed (February 1982) safety goals for nuclear power plants, which is an attempt to establish the level of risk in quantitative terms from the operation of nuclear power plants acceptable to the US community. The NRC has proposed that:

a. Individual members of the public should be provided with a level of protection from the consequences of nuclear power plant accidents such that no individual bears a significant additional risk to life and health.

b. Societal risks to life and health from nuclear power plant accidents should be as low as reasonably achievable and should be comparable to or less than the risks of generating electricity by viable competing technologies.

c. The risk to an individual or to the population in the vicinity of a nuclear power plant site of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatality risks resulting from other accidents to which members of the US population are generally exposed.

d. The risk to an individual or to the population in the area near a nuclear power plant site of cancer fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1%) of the sum of cancer fatality risks resulting from all other causes.

e. The benefit of an incremental reduction of risk below the numerical guidelines for societal mortality risks should be compared with the associated costs on the basis of $1000 per man-rem averted.

f. The likelihood of a nuclear reactor accident that results in a large-scale core melt should normally be less than one in 10,000 per year of reactor operation.

2. The safety goals are concerned only with the risks from accident situations and do not cover risks from routine emissions.

3. Ultimately, it is the intention of the NRC to use the safety goals in conjunction with probabilistic risk assessment to supplement existing licensing procedures based upon compliance with regulations. There is no intention to substitute for the current regulations, but the safety goals will be used as an additional standard against which a plant will be assessed for licensing.

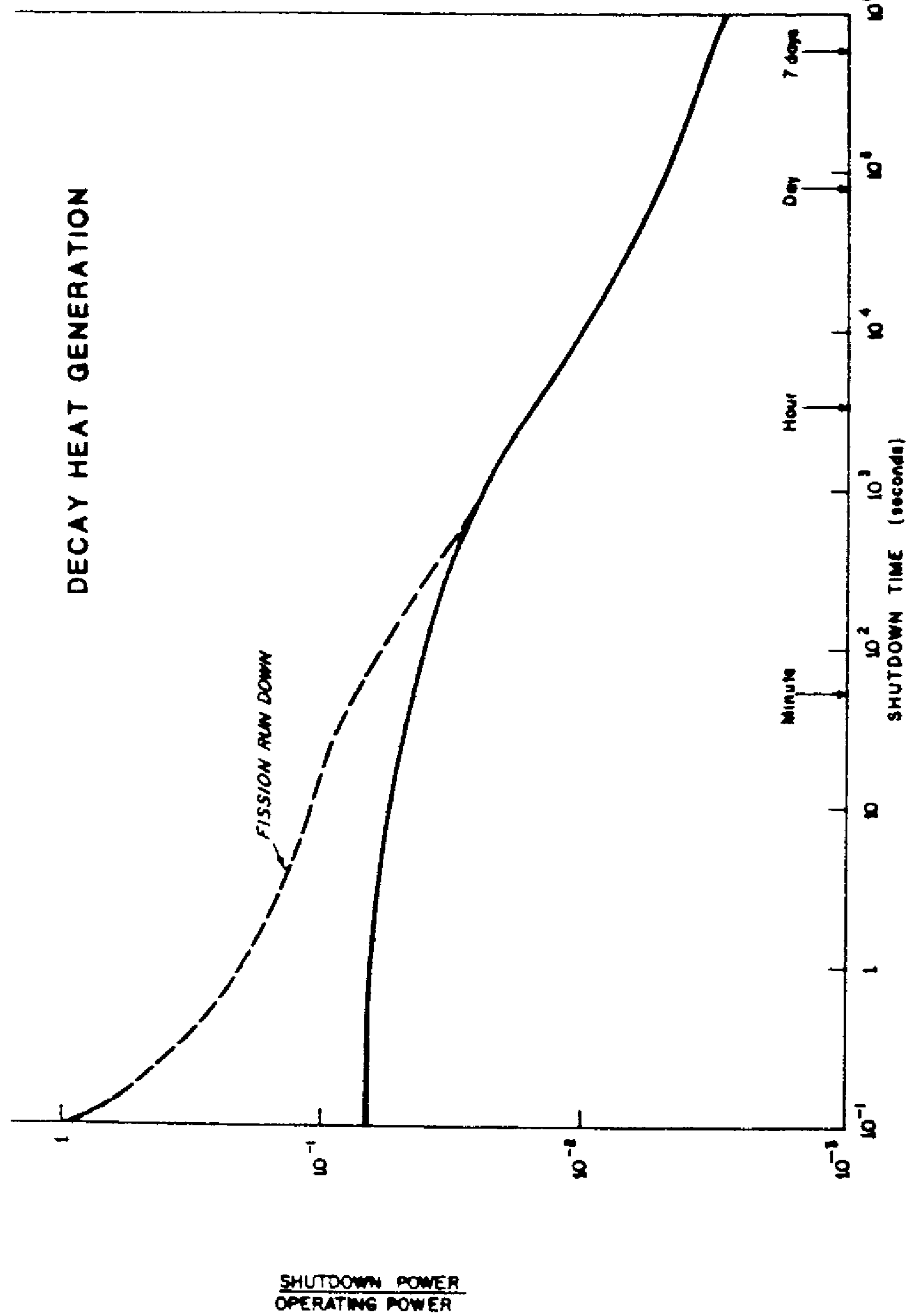

DECAY HEAT GENERATION
FISSION RUN DOWN
SHUTDOWN POWER / OPERATING POWER
SHUTDOWN TIME (seconds)
Minute
Hour
Day
7 days
1
10
10^{-1}
10^{-2}
10^{-3}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}

TABLE 1

THE CHARACTERISTICS OF SOME IMPORTANT FISSION PRODUCT NUCLIDES

Nuclide	Half-life	Activity at shut-down kCi/MW	Emission	Radiological hazard
KR 85 KR 88 Xe 133 Xe 135	10.7 y 2.8 h 5.27 d 9.16 h	0.62 23 54 25	β, γ	External; whole body
I 131	8.06 d	25	β, γ	Internal; thyroid
Te 132	78 h	38	β, γ	Internal; thyroid hazard from I 131 daughter
Sr 90	29 y	6*	β	Internal; bone and lung**
Ru 106	1.0 y	10*	β	Internal; lung, kidney and G.I. tract**
Cs 137	30 y	5.3*	β, γ	Internal; whole body
Ce 144	284 d	50*	β, γ	Internal; bone, liver, lung

* After 5 years irradiation.

** Radiation hazard from short-lived daughter.

TABLE 2

CONSEQUENCES OF HYPOTHETICAL ACCIDENTS TO 1,000 MW (electrical) NUCLEAR POWER STATION

Health Effect (per year)	Chance per Reactor per year		Normal[b] Incidence Rate in Exposed Population (per year)
	One in 20,000[a]	One in 1,000,000[a]	
Latent Cancers	<1	170	17,000
Thyroid Illness	<1	1400	8,000
Genetic Effects	<1	25	8,000

(a) The rates due to reactor accidents are temporary and would decrease with time. The bulk of the cancers and thyroid nodules would occur over a few decades and the genetic effects would be significantly reduced in five generations.

(b) This is the normal incidence that would be expected for a population of 10,000,000 people who might receive some exposure in a very large accident over the time period that the potential reactor accident effects might occur.

TABLE 3

THEORETICAL CONSEQUENCES OF 2 MAJOR HYPOTHETICAL ACCIDENT SEQUENCES

LARGE NUCLEAR POWER REACTOR (BASED ON REFERENCE 1)

Accident Sequence	Probability per year	Duration of Release (hrs)	Warning Time for Emergency Plan (hrs)	Fraction of Fission Product Inventory Released to Environment					
				Xenon-Krypton	Iodine	Caesium	Ruthenium	Tellurium	Strontium
Loss of Coolant - All Protection Functions	$4x10^{-4}$	0.5	None required	$3x10^{-6}$	$7x10^{-9}$	$6x10^{-7}$	0	$1x10^{-9}$	$1x10^{-11}$
Loss of Coolant - Core Meltdown -Partial Loss of Containment (High Leak)	$7x10^{-7}$	4.0	1.0	0.3	$3x10^{-2}$	10^{-2}	$6x10^{-4}$	$5x10^{-3}$	10^{-3}

TABLE 4

CONSEQUENCES OF MAJOR REACTOR ACCIDENTS

Facility	Description	Date	Fission Product Release to Environment - Curies			Accident Type
			Iodine	Noble Gases Xenon-Krypton	Others	
NRX (Canada)	Heavy Water Research Reactor 30MW (Thermal)	12/12/52	Not measured	10^4 in 10^6 Gallons of Water	-	Power Excursion/Loss of Coolant
WINDSCALE (UK)	Air Cooled Graphite Plutonium Production Reactor (Classified - Probably about 100MW)	10/9/57	20,000	300,000 Xenon 133 1,650 Krypton 85 (Estimated)	2 Strontium 90 600 Caesium 80 Ruthenium 12,000 Tellurium	Graphite Fire
SL-1 (USA)	Experimental Boiling Water Power Reactor 3MW (Thermal)	1/3/62	10-16 Hrs 70-30 Days	10^4 Xenon-Krypton (Estimated)	0.6 (Unidentified metal)	Power Excursion
THREE MILE ISLAND (USA)	PWR Power Plant 2700MW (Thermal)	28/3/79	13-18	$2.5 \times 10^6 - 13 \times 10^6$ Xenon-Krypton	-	Loss of Coolant

"THE NUCLEAR ATTACK PROBLEM"

Address by Dr D Williams of the
Materials Research Laboratories

Introduction

The aim of my talk is to describe the various nuclear weapon effects and attempt to identify the problems of importance to Civil Defence in a nuclear attack situation.

Nuclear Weapons

Let us start at the beginning with the weapons themselves. The first "primitive" type weapon shown in Fig 1 is based upon the rapid bringing together of two sub-critical masses of fissile material such as U^{235} or Pu^{239}.

The second, more effective type, shown in Fig. 2 is based upon the increase in density of the fissile material following implosion on a slightly under-critical mass.

Both the weapons illustrated are categorised as fission weapons because the explosive release in energy results from fission (i.e. the splitting of fissionable atoms) rather than from fusion - the building up of atoms.

Fusion weapons employ a fission triggering device as shown in Fig. 3. This generates the high temperature ($\sim$10 million degrees centigrade) required for the fusion of heavy hydrogen atoms - deuterium and tritium.

Bomb Size

The nuclear weapon used at Hiroshima consisted of about 60 kg of U^{235} (shape of football). It was 10 ft 6 ins (3.2 m) long and 29 inches (0.74 m) in diameter. The yield was 12.5 kt but only about 1% of the U^{235} was fissioned.

The Nagasaki Bomb (Fat Boy) was egg shaped - 11 ft (3.35m) in length and 5 ft (1.52 m) in diameter. It was an implosion type weapon with Pu^{239} as fissile material.

Indicative sizes of tactical (small yield) nuclear weapons are:

Davy Crockett - 2 ft (0.6m) long, 12 ins (0.3m) maximum diameter

Mark 48 artillery shell - 3 ft (0.9m) long, 6 ins diameter

Improvements in bomb design have during the course of time reduced bomb size as indicated by the small size of tactical weapons of kiloton or sub-kiloton yield. This small size may be of relevance in considering terrorist use of nuclear weapons.

A consideration in this regard would be the difficulties likely to be experienced by terrorists in the procurement of nuclear weapons or, for that matter, quantities of radioactive material. Covert or overt support by a hostile power could change this position.

Weapon Yield

The yield of a nuclear weapon is the total amount of energy released on detonation. For a ground or near ground burst of a fission type weapon this energy is partitioned into:

- 45% - blast and shock wave
- 35% - light and heat radiation
- 5% - initial radiation
- 15% - residual radiation from fission products

Units are in kiloton (kt) or megaton (Mt)

1kt = 1000 tons of TNT: 1Mt = 1,000,000 tons of TNT.

Types of Nuclear Explosion

There are five main types. Where detonation takes place:

a. on or near the ground - to maximise fallout or to destroy underground targets;

b. in shallow water - to cause damage to harbours;

c. in deep water - to create surges or to destroy submarines;

d. high in the air - optimum height of burst to maximise blast and thermal effects;

e. very high in the air - on the fringe of the earth's atmosphere for the extensive spread of EMP (electro-magnetic radiation from a nuclear explosion).

Threat Scenarios

Various threat scenarios may be postulated. For example, a nuclear attack on or involving:

a. USSR and China;

b. NATO and WARSAW Pact countries, limited to the European area;

c. USSR and USA, including attack on cities;

d. Middle East countries;

e. terrorists;

f. joint Australian/US bases;

g. Australian cities.

Each threat situation would present its own particular problems requiring an appropriate response. The worst case, as far as Australia is concerned, would be, of course, an attack on Australian cities.

In terms of weapon yield delivered, the most probable worst case envisaged would be a total yield of tens of megatons expended on Australian territory. This amount can be contrasted with the yields of thousands of megatons for the US and about 200 Mt for the UK.

A credible worst case situation may be taken as being a 1 Mt yield attack on an Australian city. The immediate effects from blast or heat radiation would cover a damaged area of around 200 km^2 which is about 10% of the built-up area of a large Australian city.* In such a case, considerable resources would escape damage and be available for post-attack relief and recuperation. However, more extensive areas would suffer radioactive fallout necessitating the implementation of protective measures for the survival of the population.

General Description: Nuclear Explosion

The explosion of a nuclear weapon results in the release of an immense amount of energy almost instantaneously. One of the first effects which can be seen in a nuclear explosion occurring in the earth's atmosphere is the formation of an intensely hot, luminous fireball which radiates light and heat in all directions. (Fig. 4).

Eye injury or impaired vision may result if the fireball is viewed directly. The intense heat radiation is capable of causing severe burns to exposed personnel and it can start fires by the ignition of flammable material.

The expansion of the fireball in the earth's atmosphere initiates a pressure wave (shock wave) accompanied by a following wind. Pressure levels and wind speeds can be sufficiently high, at large distances (kms) from the centre of the explosion, to destroy buildings or structures.

A part of the energy of the explosion takes the form of gamma rays (similar to X-rays but of higher energy) and neutrons (electrically uncharged nuclear particles). This radiation which is taken to be emitted during the first minute of the explosion is called the "initial nuclear radiation". There is also, what is termed "residual nuclear radiation" which refers to the radiation subsequently emitted over a long period of time - the main penetrating component being gamma rays. A main source of the residual radiation is the radioactive products of the explosion contained within the fireball. As the fireball developes it ascends rapidly to form a characteristic mushroom shaped cloud in the upper atmosphere. Radioactive material from within the cloud and its stem descends to the earth's surface as fallout.

* Civil Defence and Fallout - D W Posener. Conference on Civil Defence and Australia's Security, Canberra, Apr 1982.

Exposure to either the initial or residual nuclear radiation is injurious to health and could result in death when excessive.

In addition to light, heat, blast and nuclear radiation, an electromagnetic pulse (EMP) is also produced. It is capable of causing damage to electronic equipment or upsetting its operation. Although EMP may be compared with the electrical emission from a lightning stroke, it can damage equipment over a more extensive area. Protection against EMP requires more exacting protective measures than those employed against lightning strokes.

Rationale or Methodology of Nuclear Protection

A concept used in the approach to nuclear protection is that of Balanced Survivability. It is a cost effective approach in which the aim is to achieve equal survivability for each nuclear weapon effect. A simple example of the approach is illustrated in Fig. 5. Iso-damage curves are shown for three effects - thermal radiation, initial nuclear radiation and blast. The Governing Envelope indicates which effect is the primary lethality agency for weapons yields between Y1 and Y2. It is seen that initial radiation is the primary lethality agency between A and B and thermal radiation between B and C. Between A and B there is little point in hardening against blast effects or thermal radiation. Similarly between B and C there is little point in hardening against initial radiation or blast.

For tactical weapons, that is weapons with yields up to about 100 kt, initial radiation can in many cases be the primary lethality agency. For example, in the case of tank crews protected against thermal radiation and to some extent from blast, initial radiation is the primary lethality agency up to weapon yields of about 100 kt. This position applies even more so for enhanced radiation weapons (neutron bombs). In the Civil Defence case when high yield weapons are considered, blast and thermal radiation are the predominating immediate effects if EMP is neglected. Nevertheless, the delayed effect from fallout is an important consideration in Civil Defence because of its distribution over large areas which could affect a large number of people.

Blast Damage

Fig 6 indicates the ranges for blast damage to typical houses and structures for a 1 Mt ground burst. It is observed that moderate to severe damage occurs in a ring at ranges of 4 and 10 km corresponding to overpressures of 10kPa (1.5 psi) and 40kPa (6 psi). Corresponding ranges for a 10 Mt weapon are 8 and 21 km.

Apart from the lethal effects of blast, State emergency services involved in Civil Defence would face two major problems. First, there is the debris problem in a built-up area, making access for relief and rescue work difficult. Second, there would be extensive areas in which public utility services would be disrupted. Above ground structures such as pylons or poles carrying power or telephone lines would be particularly susceptible.

A third problem is that of blast resistant shelters. These would be of value in particular circumstances. However, generally, their value would depend on the warning time.

Thermal Radiation

The thermal radiation from a nuclear explosion is capable of causing skin burns to exposed people at large distances from GZ as indicated in Fig. 7. As shown, 3rd degree burns could occur at a distance of 8km for a 1Mt ground burst.

The thermal pulse would initiate fires. For a 1Mt air burst over a city, the main fire zone would be between 2.8 and 10.4 km ranges for an atmospheric visibility of around 13 km. In the case of Australian cities, it is unlikely that a firestorm as created at Hiroshima or Hamburg would result. Firestorms are more likely to occur in heavily built-up areas containing large amounts of combustible materials and where, at least, every other building has been set alight. However, particular adverse conditions prevail in Australia during high fire danger periods which are conducive to the massive spread of fire.

Fallout

As indicated previously, radioactive fallout is a principal concern of Civil Defence.

The radioactive fussion products from nuclear weapons detonated on or near the ground would condense on particulate matter raised in the mushroom shaped cloud as indicated in Fig. 8. Large particles greater than about 1.50 mm in size are deposited near GZ whereas smaller sized particles borne by the prevailing winds can be transported over long distances of several hundreds of kilometres.

There is early and delayed fallout. Early fallout is defined as that deposited on the ground during the first 24 hrs following a nuclear explosion. It gives rise to the early or immediate hazard which may last up to 2 weeks or so. Delayed fallout consists of very fine particulates which take greater than one day to be deposited and is spread over a much larger area than early fallout.

Stratospheric winds circulate the radioactive material around the world. The extent of the deposition and the time it takes to settle reduces the activity considerably. Nevertheless it gives rise to a long term hazard through the contamination of crops and the water supply.

Several hazards arise from:

a. inhalation
b. ingestion
c. body contact
d. whole body gamma radiation

Protection against whole body gamma radiation is the principal immediate concern.

Fallout Prediction

The first step in dealing with a fallout nuclear attack situation is the prediction of the fallout pattern. Various prediction methods have been developed.

a. Mathematical model

b. Analogue method

c. Danger sector forecast

d. Idealised fallout pattern.

The first approach involves a detailed mathematical treatment of the physical and chemical mechanisms involved in the fallout process. It generally requires the use of a large main frame computer.

The analogue method selects a particular fallout pattern from a catalogue of patterns based upon similarity of weapon yield, wind velocities etc.

The danger sector forecast (as used by several Civil Defence organisations), takes into account wind vectors and identifies sector areas in which fallout would likely occur.

The idealised fallout contour pattern approach predicts the average fallout field for a given weapon yield and average wind velocity. This type of pattern is illustrated in Fig. 9. A more realistic pattern that might be produced is shown in Fig. 10. "Hot Spots" occur in this pattern which are attributed to local meteorological conditions.

Protection Against Gamma Radiation

Protection against the gamma radiation from fallout may be achieved in several ways:

a. Exploitation of the inverse square law;

b. Shielding by material obstacles;

c. Removal from the fallout area (including evacuation).

The radiation intensity at a distance (excluding attenuation) is inversely proportional to the square of the distance. Thus, in application, additional protection would be provided by an inner room of a building compared with that of an external room nearer the source of radiation.

The intensity of gamma radiation is progressively reduced as it penetrates materials and the protection provided increases with the weight of material interposed between the source and recipients. It follows an exponential law for a given energy of radiation and narrow source to target geometry.

The shielding provided can be conveniently considered in terms of half-value thickness which reduces the dose rate by a factor of two. This is illustrated in Fig. 11 which also gives half-value thicknesses for some common materials.

Evacuation (or relocation) of sections of the population is an obvious approach to protection. Extensive relocation, however, may be considered to be impractical as it presents many problems in addition to the provision of suitable accommodation.

Protection requirements are somewhat eased by the (relative) rapid decay of the 300 or so fission product isotopes. The average decay rate for these fission products follows a $t^{-1.2}$ law. Application of this law shows that the dose rate drops by a factor of 1/1000 in a period of two weeks.

A particular concern is the protection provided by buildings or shelters. This can be expressed in terms of the protection factor (PF) defined as:

$$PF = \frac{\text{Dose rate on smooth ground in the open}}{\text{Dose rate within building}}$$

Protection factors for various buildings and structures are shown in Fig. 12. It is seen that only limited protection is provided by domestic buildings and that far greater protection is provided by concrete shelters or office blocks. Furthermore, underground shelters have an obvious advantage.

An approach favoured by some countries involves the construction of expedient shelters. Such earth-covered fallout shelters provide good protection and can be constructed within 48 hours by people with little building skills. More effort, materials and skill is required to build expedient blast shelters.

<u>Magnitude of the Fallout Problem</u>

In a nuclear attack or nuclear war situation it is required to nominate, what is called in the UK - a wartime emergency dose - for essential operational tasks during and immediately after a nuclear attack. In the UK it is taken that as a general rule a WED of 75 r (which may be approximated to 750 mSv) would be the maximum permissable in the execution of essential operational tasks. This value, although very high by peacetime standards may be used as a benchmark in assessing the threat posed by fallout.

The extent of fallout areas for various weapon yields is shown in Fig. 13. Clearly, these figures indicate that large numbers of people in a populous area would be seriously at risk if no significant protection is provided. For example, taking a 2Mt yield weapon the area of the 100 r (1000 mSv) per hour contour is 5120 km^2. A similar situation is shown in Fig. 14 where the BRAVO test fallout pattern is superimposed on a map of Victoria.

There is no doubt that a population could be protected against fallout provided that in a contaminated area, people remain suitably sheltered for periods up to 2 weeks or so. They would, of course, require suitable supplies of food, water and other essentials for survival. A secondary problem following the initial post-attack phase is the hazard presented by the consumption of contaminated food and water.

Civil Defence Response to Nuclear Attack

A Civil Defence response to a nuclear threat embraces many features. An indicative listing shown in Fig. 15 is:

a. Policy and Planning

b. Machinery of Government

c. Warning and Monitoring Organisation

d. Role of the State Emergency Services.

Policy and Planning would include consideration of:

a. Planning Assumptions - scale, magnitude and nature of the threat.

b. Planning Objectives - measures required to provide essential supplies.

c. Warning Period - development of a crisis situation. Warning time available against impending attack.

d. Provision of Shelters - blast and fallout shelters.

The machinery of government is an issue in that the consequences of a nuclear attack may render central government inoperative. Decentralised government may be required for a period.

A Warning and Monitoring Organisation is clearly essential. A population needs to be warned of an impending attack and subsequently on fallout. A first need is the prediction of fallout based upon burst parameters. Second, predictions need to be updated as fallout measurements become available. A suitable meteorological service is required to provide necessary data. Control and monitoring posts are required to establish fallout patterns possibly by a variety of means - in-situ, vehicular or aerial instrumentation: RADIAC instrumentation is required to determine weapon yield, GZ, HOB of the nuclear explosion. Various dosimeters and survey meter are required. Scientific support is necessary in order to predict, analyse and interpret relevant scientific data.

It would be expected that in Australia, the State emergency services would play a vital role. Training of such personnel would be essential.

Conclusions

A nuclear attack situation differs radically from a peacetime radiation incident. It involves the consideration of the various nuclear weapon effects - blast, thermal radiation, initial radiation, residual radiation and EMP. In the case of high yield weapons, blast and thermal radiation are the dominant initial effects around GZ. Fallout, because of its extent, is of primary importance. EMP damage ranges extends from kilometres to thousands of kilometres distance depending on burst parameters.

The spread of fire during high fire danger periods poses a particular threat in Australia.

Electronic equipment is generally vulnerable to EMP. Communication systems of national importance as well as those of specific interest to Civil Defence are at risk unless suitably protected.

A particular concern is the provision of suitably designed blast and fallout shelters which could include expedient shelters.

An appropriate Civil Defence response embraces Policy and Planning, the Machinery of Government, Warning and Monitoring Organisation and the role of the State emergency services. Relevant organisations need to be equipped with suitable RADIAC instrumentation and trained accordingly.

Comprehensive studies are an integral part of an appropriate Civil Defence response. A short listing comprises:

a. Vulnerability analyses and protective measures appropriate to the Australian situation.

b. Spread of fire during adverse weather conditions.

c. Vulnerability of communication systems to EMP and required protective measures.

d. Fallout prediction methods, monitoring, data analysis and display; modern approaches to the determination of fallout patterns.

e. Organisational approaches.

f. Training of personnel and public education.

NUCLEAR WEAPONS - GUN TYPE

CRITICAL MASS GREATER THAN 5KG. U^{235}

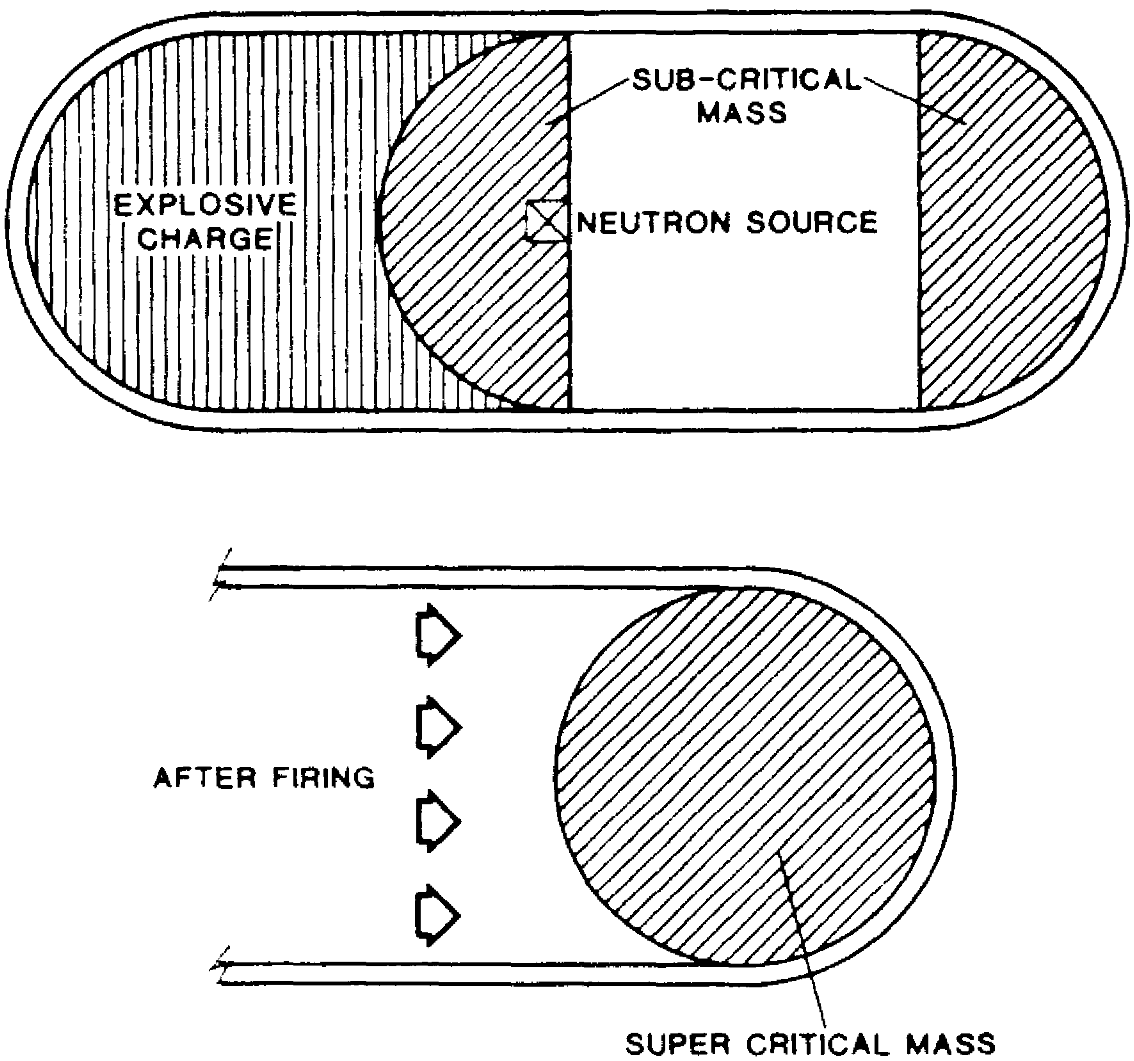


FIGURE 1.

NUCLEAR WEAPONS - IMPLOSION TYPE

CRITICAL MASS GREATER THAN 3KG PU^{239}

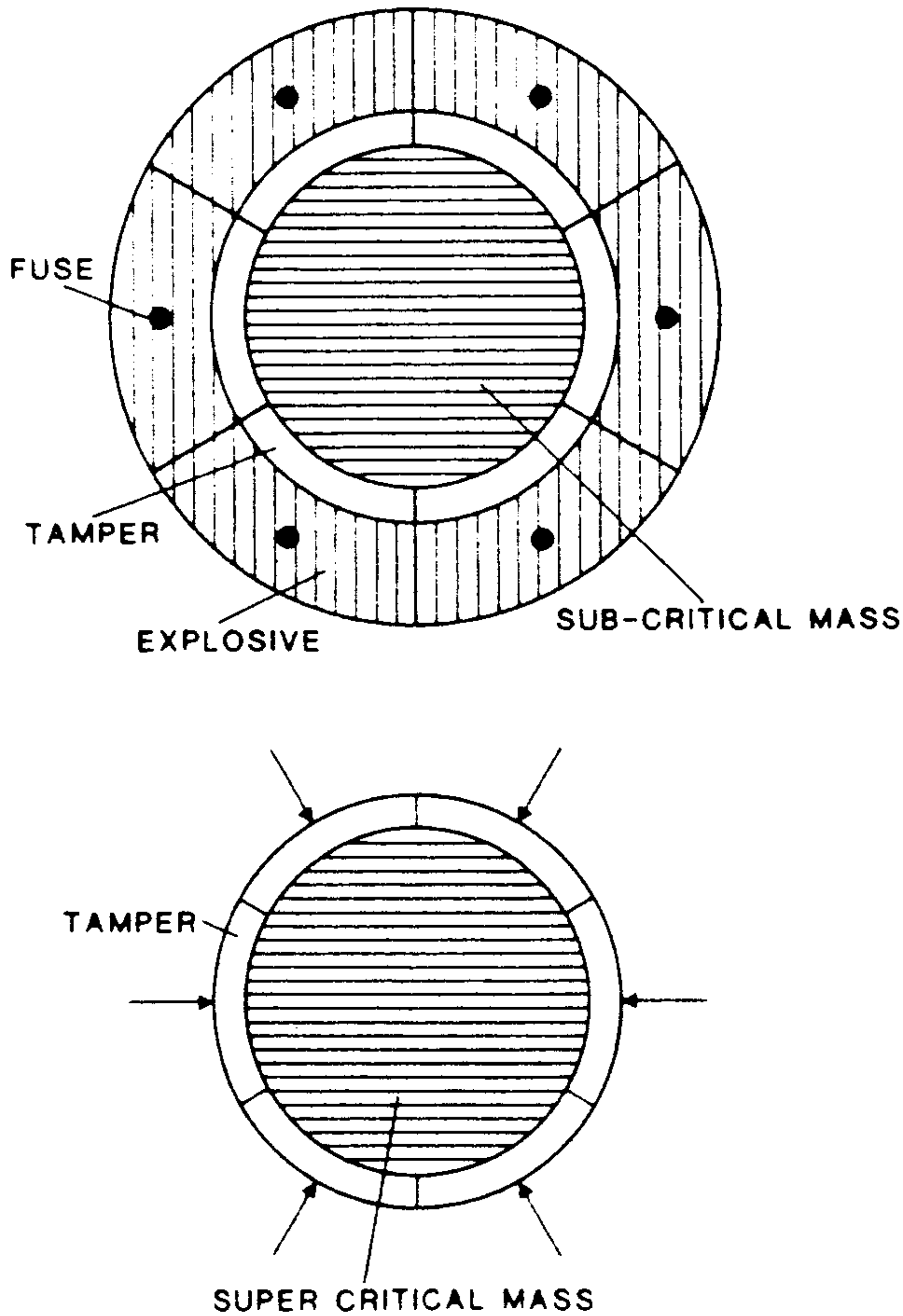


FIGURE 2.

NUCLEAR WEAPONS - FUSION

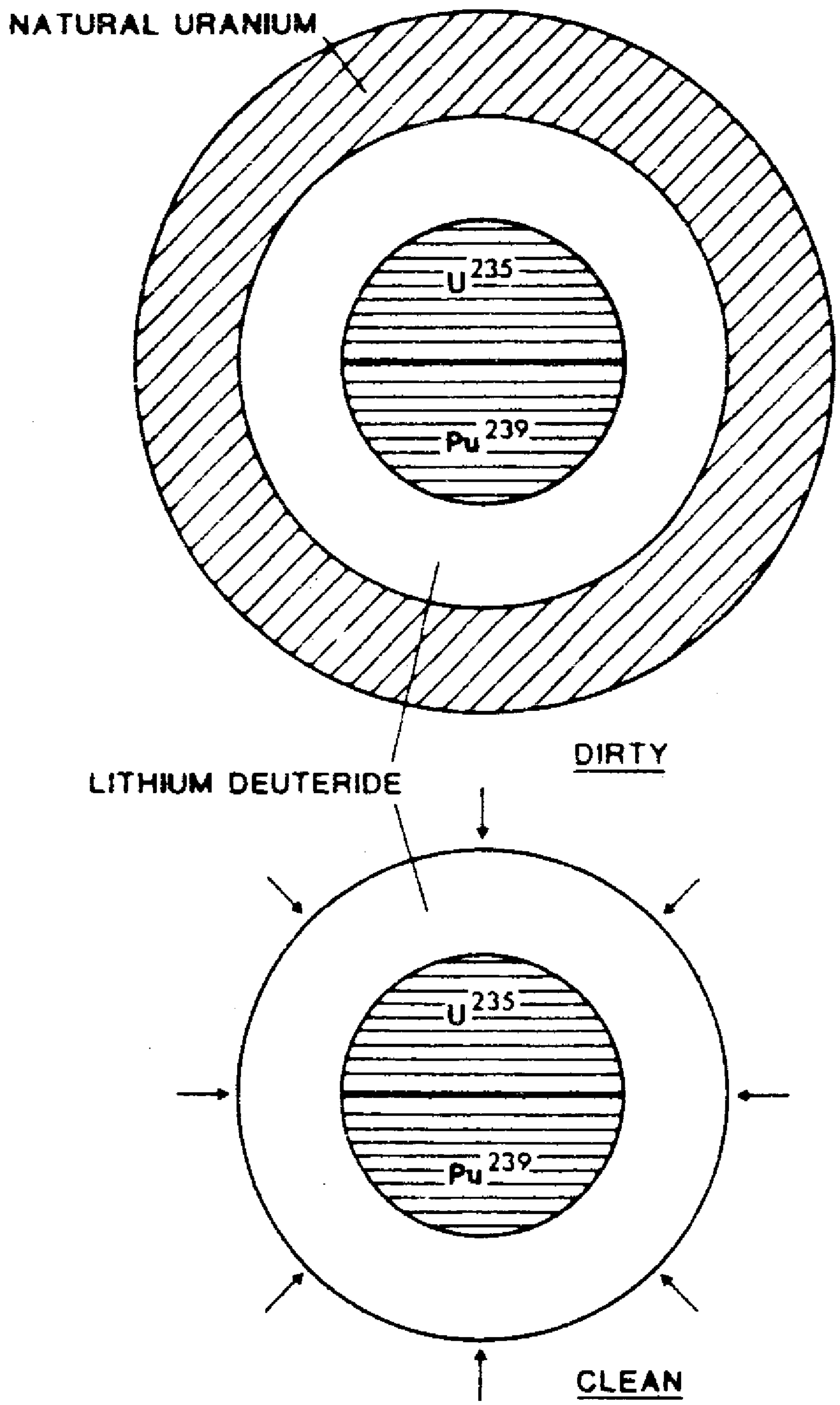
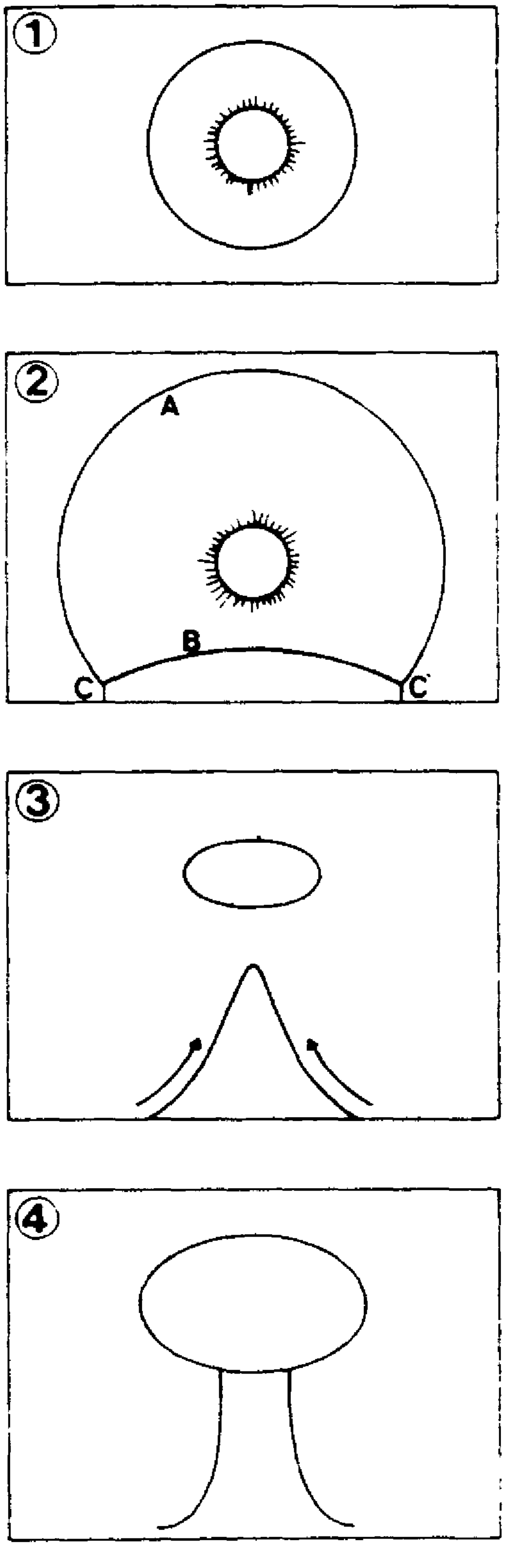


FIGURE 3.



FIREBALL, BLUISH-WHITE BLINDING FLASH, SURROUNDING TEMPERATURE 10,000,000° C

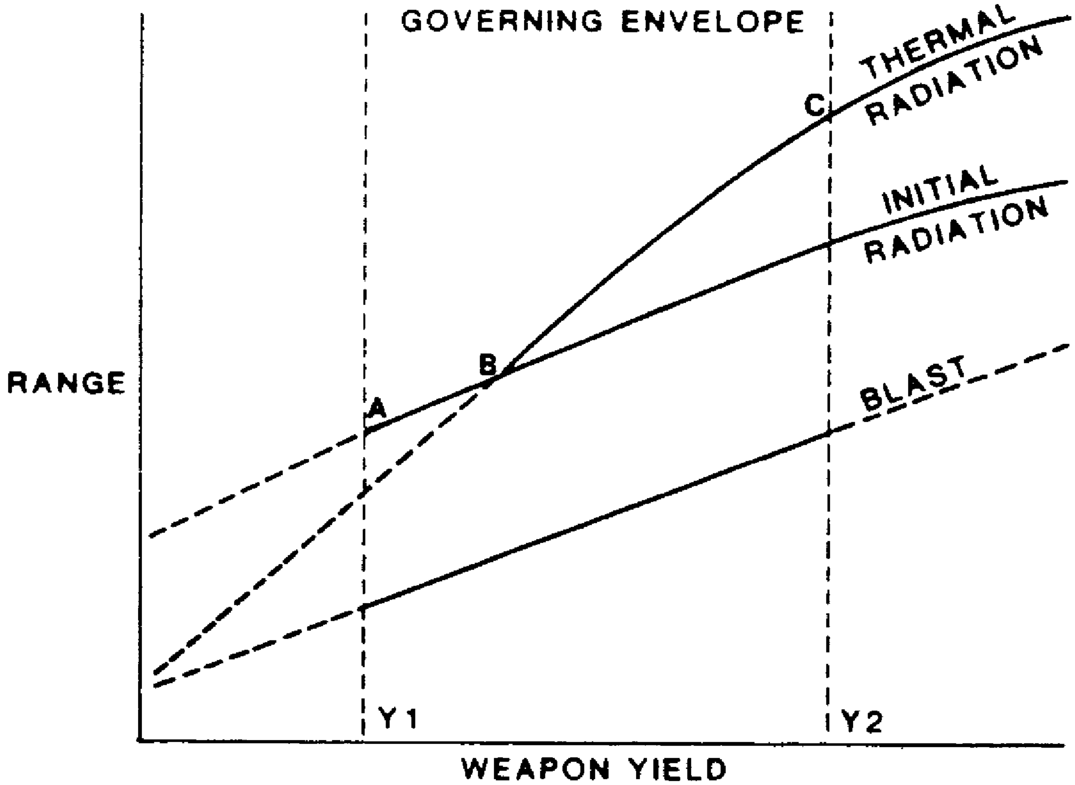
HEATWAVE FOLLOWED BY PRESSURE WAVE (A), REFLECTED PRESSURE WAVE (B) HAS DOUBLED INTENSITY TO FORM "MACH WAVE" (C)

OVERPRESSURE WAVE IS FOLLOWED BY NEGATIVE PRESSURE PHASE WHICH DRAWS WINDS UP TO 1100 KM/HR.

DIRT AND DEBRIS SUCKED INTO RISING COLUMN OF HOT GASES AND SMOKE TO FORM MUSHROOM CLOUD

FIGURE 4.

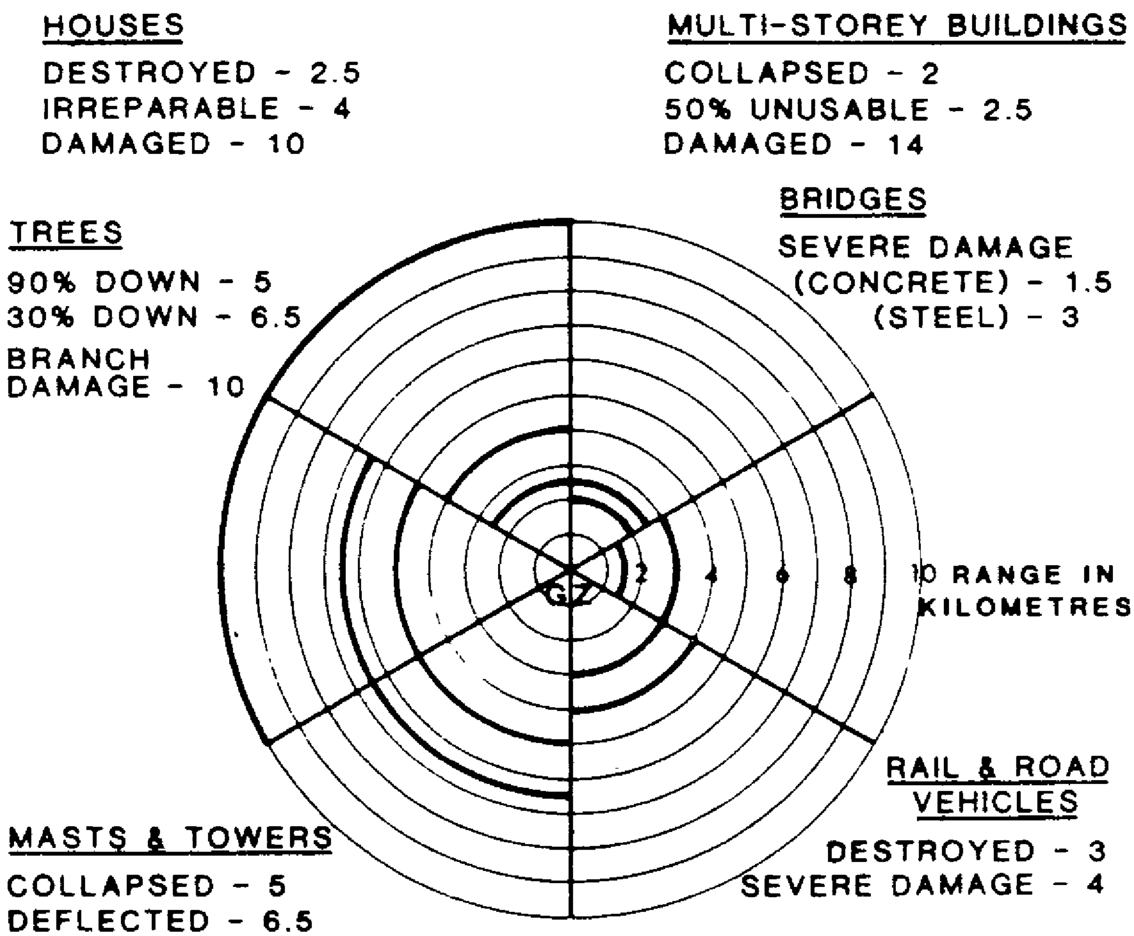
BALANCED SURVIVABILITY



THREAT SPECTRUM - BETWEEN Y1 AND Y2 YIELDS

FIGURE 5

BLAST DAMAGE : 1 MT. YIELD



STREETS IMPASSABLE - 2.5
" BLOCKED (NEED MECHANICAL CLEARANCE) - 4
" PROGRESS DIFFICULT - 10
" LITTERED WITH GLASS & TILES - 14

FIGURE 6.

RANGE (FROM GZ) OF HEAT EFFECTS ON PEOPLE

CONDITIONS:
GROUND BURST, CLEAR ATMOSPHERE

WEAPON YIELD	20KT	0.1MT	0.5MT	1MT	2MT	10MT
SKIN CHARRING	1.00	2.00	4.00	5.00	6.75	12.00
" BLISTERING	1.25	2.50	4.75	6.25	8.25	16.00
" REDDENING	1.75	3.25	6.50	8.50	11.00	20.00

FIGURE 7.

RADIOACTIVE FALLOUT

GROUND BURST 2MT.

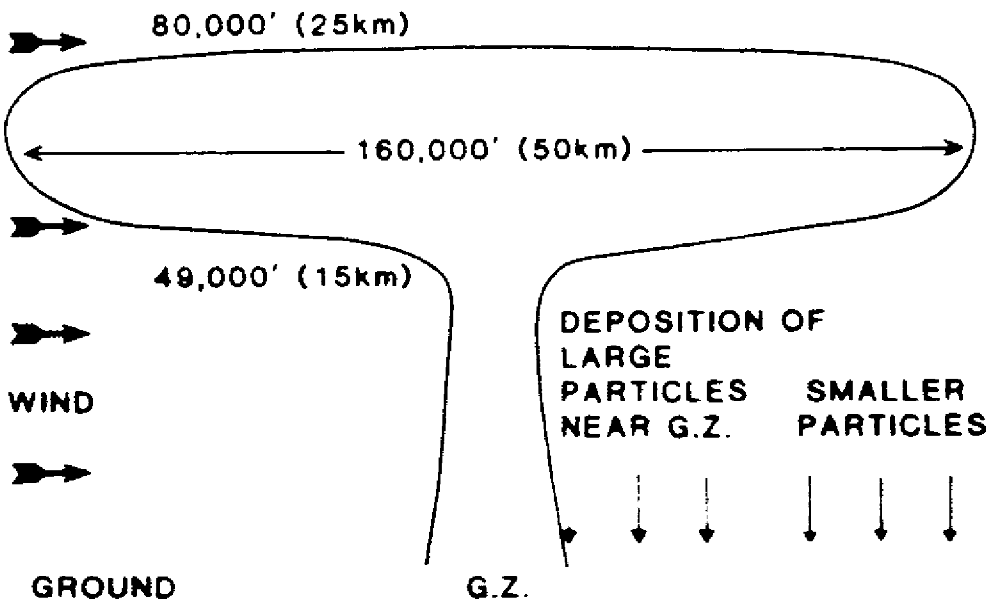
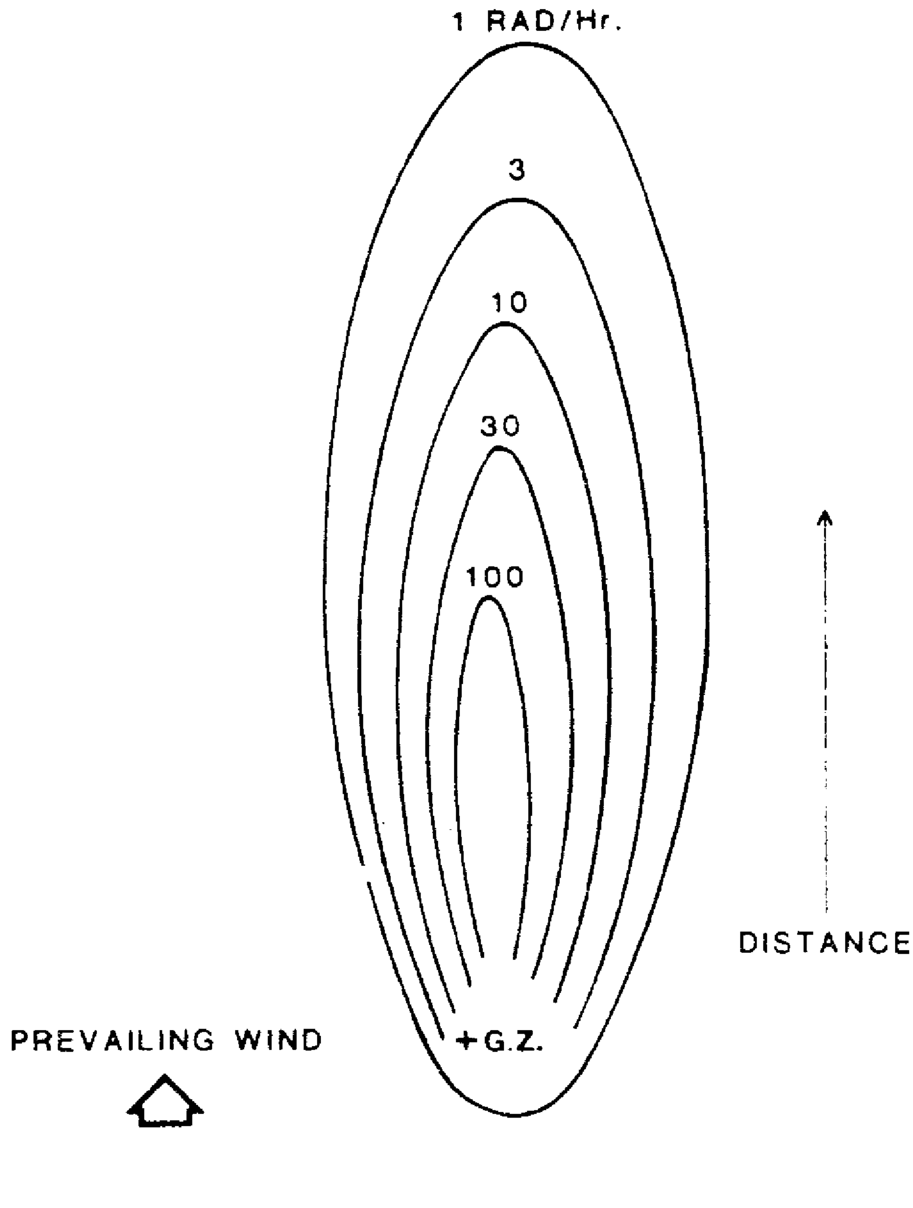
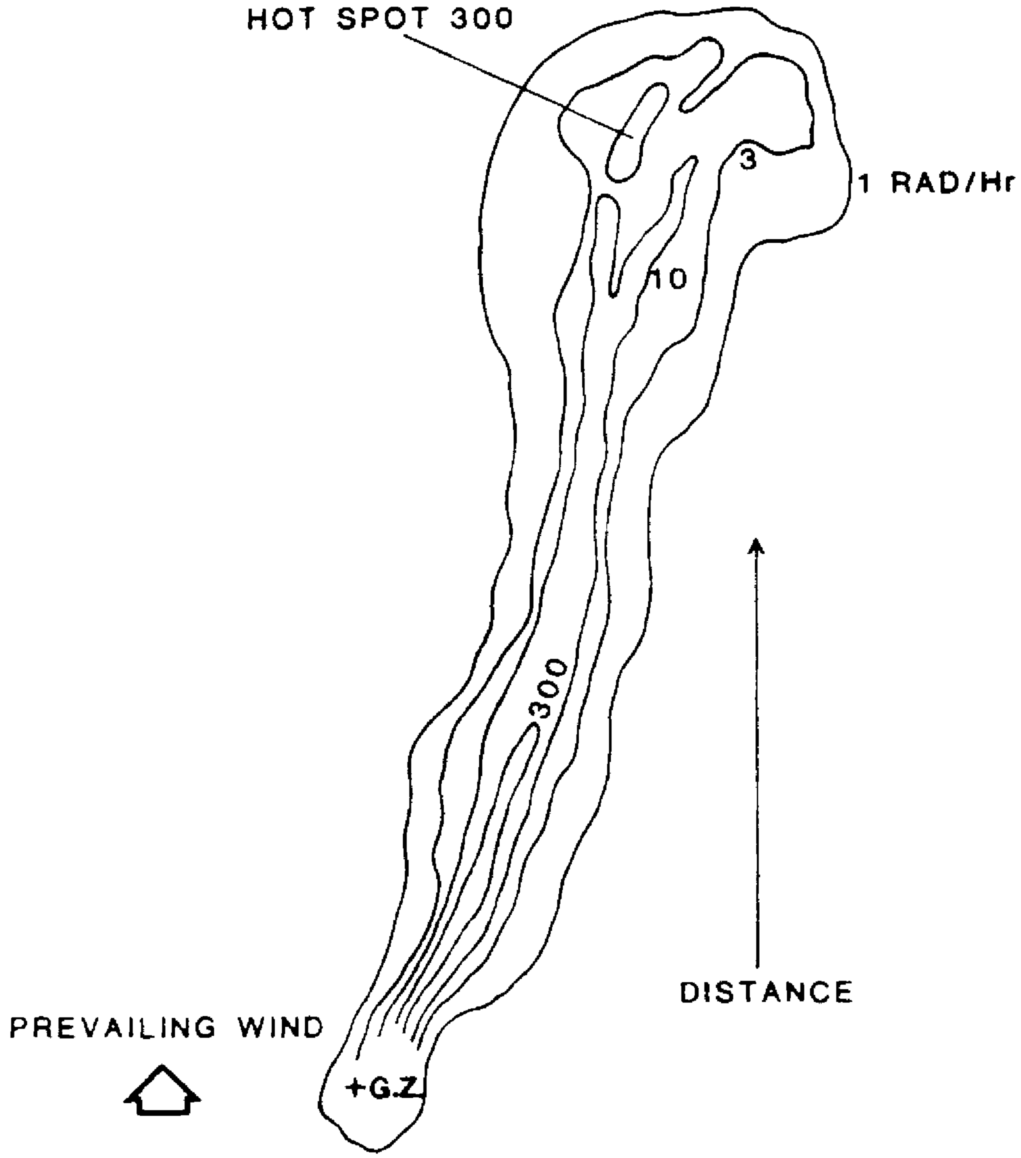


FIGURE 8.



FALLOUT PATTERN - IDEALISED

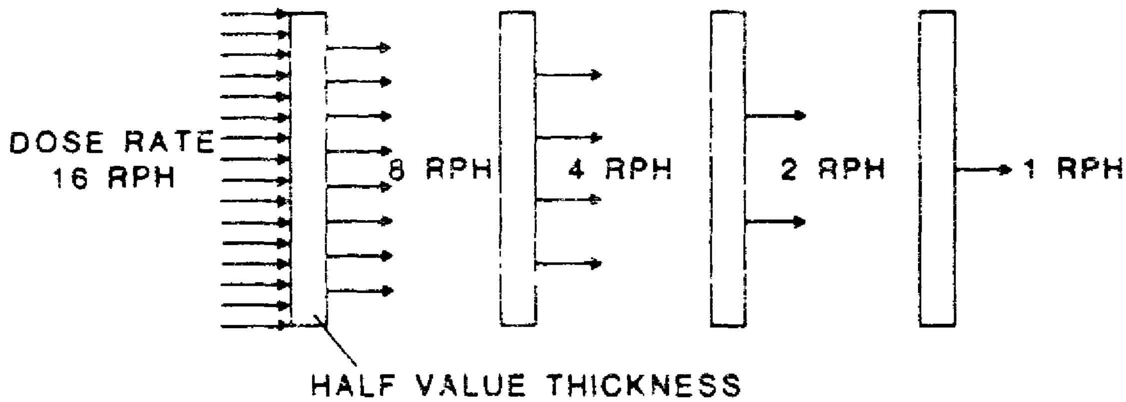
FIGURE 9.



FALLOUT PATTERN – REALISTIC

FIGURE 1[illegible]

HALF-VALUE THICKNESS



MATERIAL	*SLAB DENSITY	HALF-VALUE (INCHES)
STEEL	41	0.7
CONCRETE	12	2.2
BRICK	10	2.8
EARTH	8	3.3

*POUNDS PER SQUARE FOOT FOR ONE INCH THICKNESS

FIGURE 11

PROTECTION FACTORS

MAINLY U.K. TYPE BUILDINGS FALLOUT RETAINED ON ROOF

TYPE	PROTECTION FACTORS
BUNGALOW	5 - 10
DETACHED TWO STOREY	15
BLOCKS OF FLATS, OFFICES	50 - 5000
CONCRETE BLOCKHOUSE (24" WALLS)	500 - 1000
THREE FEET UNDERGROUND	5000
FRAME HOUSE	1.6 - 3.3

FIGURE 12.

AREAS OF CONTOURS DOWNWIND FALLOUT

REFERENCE DOSE RATE 1 HOUR AFTER FALLOUT

50% FISSION FOR YIELDS $>$ 0.5 MT

100% FISSION FOR LOWER YIELDS

REFERENCE DOSE RATE R.P.H.	AREA IN SQUARE MILES			
	100KT	1MT	2MT	10MT
3000	1.2	20	40	200
1000	6.4	90	190	900
300	25.0	300	700	3500
100	82.0	900	2000	9000
30	250.0	2000	4000	22000
10	1000.0	4500	9000	47000

FIGURE 13.

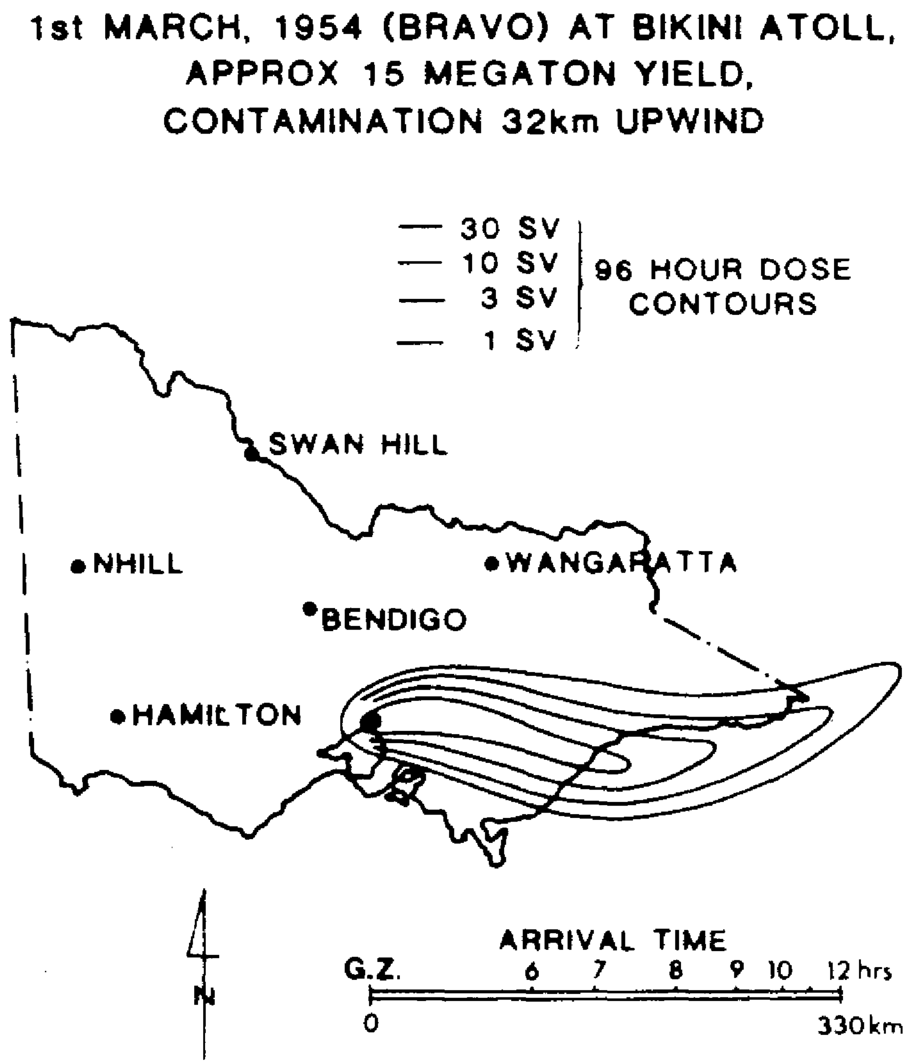

1st MARCH, 1954 (BRAVO) AT BIKINI ATOLL,
APPROX 15 MEGATON YIELD,
CONTAMINATION 32km UPWIND
30 SV
10 SV
3 SV
1 SV
96 HOUR DOSE CONTOURS
SWAN HILL
NHILL
WANGARATTA
BENDIGO
HAMILTON
N
ARRIVAL TIME
G.Z.
6
7
8
9
10
12 hrs
0
330km

FIGURE 14.

CIVIL DEFENCE RESPONSE

A. *Policy and Planning .*

B. *Machinery of Government .*

C. *Warning and Monitoring Organisation .*

D. *Role of the State Emergency Service .*

FIGURE 15

ARRANGEMENTS TO COPE WITH A NUCLEAR REACTOR ACCIDENT, OR OTHER ACCIDENTS INVOLVING IONISING RADIATIONS AND RADIOACTIVE MATERIALS

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Australian Atomic Energy Commission Research Establishment,
Lucas Heights, NSW

Introduction. The potential for harm of ionising radiations and radioactive materials, if they are not properly controlled, has been realised since the beginning of this century. Extensive experience has been gained in their use in many fields of application over the past several decades and, during this period, there has been a significant expenditure, in terms of manpower and money, to minimise the possibility of the occurrence of radiological accidents. In spite of this effort some accidents have occurred (1); many of these have been caused by human error. As in other fields of human endeavour, the absolute prevention of accidents, when using ionising radiations and radioactive materials, may not be possible.

Radiological Accidents - General

A radiological accident may be defined as an unforeseen occurrence involving exposure of humans and their environment to unexpected ionising radiation and radioactive materials. A broad categorisation of radiological accidents includes:

a. external radiation accidents involving external irradiation of (at most) a few persons;

b. radioactive contamination accidents involving external contamination, possibly internal contamination and perhaps some external irradiation of persons, eg involving persons working with radioactive materials in a laboratory or similar area;

c. intermediate scale radiological accidents where the effects are confined to a relatively limited area, eg an accident in a building involving the spread of radioactive contamination throughout part or all of the building, but no extensive dispersal outside the establishment, and with any external radiation hazard restricted to the immediate vicinity of the accident;

d. major radiological accidents involving widespread dispersal of radioactive materials to the environment outside the establishment or facility where the accident occurs. This type conceivably could involve major local

d. (continued)
radioactive contamination and external irradiation hazards, together with widespread contamination of varying degree, and possibly some external irradiation hazards in the surrounding environment.

Two phases may be envisaged for a radiological accident:

a. the accident proper; this period may vary from seconds to days and may not always be amenable to controls to limit its duration,

b. the accident control period; this may vary from hours to many days and involves the time taken to shield or remove radiation sources giving external irradiation hazards, to control or remove sources of contamination, to introduce other remedial measures and return conditions to normal. Without adequate planning this period may give rise to unnecessary exposure of personnel to ionising radiation or radioactive materials.

Radiological Accidents with Release of Radioactive Materials to the Environment

An accident involving a release to the environment of significant amounts of radioactive materials could give rise to hazards from:

a. external radiation from an airborne cloud of released radioactive materials which emit penetrating ionising radiation;

b. external radiation from radioactive materials, emitting penetrating ionising radiation, which are deposited on the ground;

c. internal radiation from inhalation of airborne radioactive materials;

d. internal radiation from ingestion of foodstuffs contaminated by the released radioactive materials.

Potential Types of Radiological Accidents

Under peacetime conditions a number of radiological accidents may be envisaged which could affect members of the general public. These include accidents involving:

a. a land-based nuclear reactor;

b. a nuclear facility, or other establishment, where significant quantities of radioactive materials are used;

c. an aircraft carrying nuclear weapons;

d. a satellite carrying a radioisotope-powered source;

e. a nuclear powered ship;

f. radioactive materials being transported by air, road or rail, (e.g. from supplier to customer);

g. a sealed radioactive source of significant activity (e.g. an industrial radiography source) which is lost, misplaced or stolen.

Preplanning for Handling Radiological Accidents

Each project, or group of projects, at an establishment or facility involving significant use of ionising radiations and radioactive materials should be subjected to a detailed safety assessment[2] which takes account of all credible conditions likely to result in a radiological accident. A contingency plan, which makes adequate provision for dealing with foreseeable accidents should then be formulated. Such a plan cannot always foreshadow every possible detail; it should be flexible and as simple as possible. If the plan is based on the worst hypothetical radiological accident envisaged at the establishment or facility then it should be capable of dealing adequately with all less serious radiological accidents which may occur there.

The contingency plan, for a hypothetical accident involving a significant release of radioactive materials to the environment should include consideration of:

a. where, in what ways, and by which routes such a release may cause adverse effects on persons and property;

b. the methodology (e.g. radiological monitoring of the environment) required to determine the magnitude and extent of the release;

c. the protective measures (countermeasures) necessary to minimise the effects of the released radioactive materials on persons in the neighbourhood;

d. the responsibility for, and methods of, implementing countermeasures;

e. the individual functions and responsibilities of the various authorities who will be involved in dealing with the consequences of the accident, and details of the liaison arrangements between them;

f. the designated authority responsible for providing information to the news media and the public on all aspects of the accident.

78\. The effects of a radiological accident involving a significant release of radioactive materials[3] [4] [5] (e.g. an accident to a nuclear reactor) will depend upon factors such as:

a. the source term (i.e. the amounts and types of radioactive materials released);

b. the type of release (i.e. whether it is a puff release, a continuous release over a long period of time or some intermediate type of release);

c. the meteorological conditions which prevail during the period of the release.

<u>Emergency Planning Zones</u>[3]

The potential for radiological accidents at an establishment or facility using significant quantities of radioactive materials should be assessed and analysed in terms of projected off-site consequences. Areas around the establishment or facility likely to be affected should be characterised taking account of their use and the population occupying them so that appropriate emergency planning zones (EPZ) may be identified to enable formulation of the necessary protective measures. Each EPZ may be regarded as approximately annular and centred on the establishment or facility. Sectors and segments of each EPZ may require special planning considerations according to their individual characteristics or the wind direction at the time of an accident.

EPZs may be established for two basic types of exposure pathways arising from a radiological accident giving rise to atmospheric release of radioactive materials:

a. a short term plume exposure pathway where external or internal exposure to persons arising from exposure to the released radioactive plume is of importance;

b. an ingestion exposure pathway where internal exposure of persons may subsequently arise by consumption of contaminated foodstuffs (e.g. milk and vegetables).

Protective measures that need to be implemented for the ingestion pathway may involve geographical areas much larger than those needed for the plume exposure pathway.

<u>Radiological Measurements During an Accident Involving Radioactive Materials Released to the Environment</u>

For a radiological accident involving release of radioactive materials to the environment a variety of radiological measures are needed; these vary in detail according to the type of radioactive materials released. They include measurements of:

a. cumulative radiation doses to persons affected by the accident;

b. external dose rate from the airborne plume or radioactive material deposited on the ground and other surfaces;

c. concentrations of airborne radioactive materials;

d. levels of radioactive contamination on surfaces and persons;

e. concentrations of radioactive materials in foodstuffs (e.g. radioiodine in milk).

The levels of radiation and contamination likely to be encountered in such an accident are generally orders of magnitude less than those in a nuclear warfare situation. Some of these measurements may be made in the field using portable radiological instruments; others may need to be made on samples brought back to a laboratory for more detailed analysis. Such laboratory measurements would include analysis of foodstuffs for specific radionuclides (e.g. ^{90}Sr). Whilst gamma-spectrometry may, in principle, be used in the field for identification of specific gamma-emitting radionuclides, in practice more accurate and detailed analyses would need to be done in a laboratory.

Protective Measures

A number of protective measures may be needed in a radiological accident involving release of significant amounts of radioactive materials. These include:

a. sheltering by persons downwind from the accident;

b. evacuation of persons from the accident area and from the areas affected by the accident;

c. radioactive prophylaxis,

d. restriction of the use of contaminated foodstuffs;

e. control of access to and egress from areas which are contaminated or where higher external radiation levels are present;

f. medical care of contaminated and irradiated persons(6) (7) (8);

g. use of personal protective devices, such as respiratory protection or protective clothing (more appropriate for protecting emergency teams than for protecting the general public);

h. decontamination of persons and areas;

i. use of stored animal feed.

80. Selection of protective measures, in a given radiological accident, should be based on their effectiveness in reducing the dose to exposed persons. Effort should not be expended on measures which are of questionable value or marginal in effect. In general it is appropriate to implemen protective measures only when their social cost and risk will be less than those which would result from the radiological exposures which would occur if the protective measures are not used.

Radioactive Prophylaxis

Radioactive prophylaxis involves the administration to persons of specific stable (i.e. non-radioactive) chemical compounds which reduce or block the uptake into body organs of certain radionuclides. An example is the use of stable iodine (as potassium iodate or potassium iodide) if there is a likelihood of intake of ^{131}I, or other radioiodines, which concentrate in the thyroid gland. After an intake of ^{131}I the quantity of iodine in the thyroid reaches a maximum within one to two days; about half this maximum value is reached in about six hours. Thus prophylactic use of stable iodine should be implemented before exposure to inhalation of radioiodines, or as soon as practicable thereafter.

Administration of stable iodine within six hours after intake of radioactive iodine will reduce the radiation dose to the thyroid by about 50%. If administered more than 12 hours later little reduction in radiation dose to the thyroid is achieved. Administration of stable iodine 24 hours after exposure to radioiodines is ineffective.

The consensus viewpoint on the recommended amounts of stable iodines for prophylactic use in the event of exposure to radioiodine is as follows:

a. All individuals above age of 1 year. During first 24 hours: 130 mg KI or 170 mg KIO_3. Every day following first 24 hours: 65 mg KI or 85 mg KIO_3.

b. Infants under age of 1 year. Every 24 hours: 65 mg KI.

Administration of stable iodine compounds should not be continued unnecessarily and it is recommended that the maximum total amount administered should not exceed one gram. The appropriate public health authority should recommend when stable iodine prophylaxis is to be used.

Administration of stable iodine does not protect organs of the body other than the thyroid. There are no prophylactic measures generally recommended for accidental exposure to other radionuclides.