Significance of Radioiodines

In the event of a reactor accident releasing fission products to the atmosphere, of most concern would be the fate of the radioactive iodine isotopes (radioiodines), especially the longer-lived iodine 131 (half-life equals eight days). The Windscale (United Kingdom) accident in 1957 brought the realisation that during the first few weeks after an accident, iodine 131 could be at least 100 to 1000 times more significant than other fission products such as strontium 90. The reasons for this are the abundance of radioiodines in fission products, their volatility, their biological specificity and their ready incorporation into food chains. About a third of all nuclear fissions give rise to radioiodines somewhere in their radioactive decay chain. About three per cent of all fissions give rise directly to iodine 131, which is a biological hazard as significant as all the other radioiodines combined. Iodine and many of its compounds are quite volatile, even at room temperature, and are readily released as vapour if exposed to the atmosphere.

Decontamination

If a radiological accident causes significant radioactive contamination consideration must be given to decontamination procedures. If persons are externally contaminated a simple soap and water wash will often be effective. However persistent personal contamination needs more stringent measures which must be carried out under the supervision of persons knowledgeable in these matters. In all cases contamination monitoring of the individual is required to ensure the effectiveness of the personal decontamination procedure used.

Decontamination of inanimate surfaces may be effected by methods such as:

a. washing, with water hoses, of vehicles, paved surfaces, building roofs and external walls;

b. mechanised flushing of streets (e.g. with street cleaning vehicles);

c. mowing of lawns and disposal of grass clippings;

d. scraping of contaminated topsoil and its appropriate disposal.

Fixation of Remaining Radioactivity

After decontamination of inanimate objects some radioactive contamination may remain, and this should be fixed to prevent its spread or resuspension. Fixation methods may include:

a. sealing road surfaces with asphalt,

b. painting, or repainting equipment or houses;

c. covering contaminated soil with uncontaminated soil or sand.

Australian Resources for Dealing with Radiological Accidents Involving Release of Radioactive Materials to the Environment

Bearing in mind the levels of radiation and contamination likely to be encountered in such an accident the main resources at the Commonwealth level for dealing with this type of radiological accident lie with the Australian Atomic Energy Commission in New South Wales and the Australian Radiation Laboratory in Victoria. The Australian Military Force has a modicum of relevant experience but their knowledge and experience is generally oriented towards the nuclear warfare situation.

Each State in Australia has a Radiation Branch, or equivalent with relevant experience and expertise. However their staff numbers are generally limited.

The State Emergency Services currently do not generally have ongoing programs relating to radiological accident assistance. Any knowledge they have is generally biased towards the nuclear warfare situation as are the radiological instruments available to them.

Consideration of Potential Radiological Accidents in Australia

Accidents Involving Land Based Nuclear Reactors

It is emphasised that under no circumstances can any accident to a nuclear reactor give rise to effects similar to those produced by the explosion of a nuclear weapon. A nuclear reactor contains within its core a large quantity of fission products; this quantity depends upon the power at which the reactor has operated and the period of time for which it has operated. If part of this fission product inventory is accidentally released to the atmosphere then persons in the environs of the reactor may be at risk.

There are only two land based reactors (HIFAR and Moata) in Australia, both of which are operated by the Australian Atomic Energy Commission (AAEC) at the Lucas Heights Research Laboratories in New South Wales.

The Moata reactor is an American Argonaut type nuclear reactor of low power and it is unlikely that any accident involving this type of reactor could give rise to a significant release of fission products to the environment.

The HIFAR reactor is one of the British DIDO class of nuclear reactors. Whilst accidents, involving release of fission products to the atmosphere, may be envisaged for this class of reactor, a number of such reactors have been operated for many years in Australia, Britain, Scotland, Denmark and Germany and in no case has there been any accident involving environmental release of fission products.

The AAEC has published its emergency plan APTCARE[10] (A Plan to Cope with Accidents at the AAEC Research Establishment

Lucas Heights NSW). The current edition of APTCARE is undergoing revision.

Accidents at Nuclear Facilities

The only nuclear facility in Australia is the Australian Atomic Energy Commission Research Establishment at Lucas Heights Research Laboratories in New South Wales. This establishment has never had any accident involving release of radioactive materials to the environment which could adversely affect members of the public. Other Australian establishments where radioactive materials are used, have limited inventories of such materials and also have no record of accidents likely to affect the public.

Accidents during Transport of Radioactive Materials (11)

Stringent regulations relating to the transportation of radioactive materials have been made at both the national and international level. Whilst there have been some accidents throughout the world during transport of radioactive materials none has given rise to significant consequences. Within Australia there have only been a few minor accidents of this type.

Accidents Involving Sealed Radioactive Sources (12) (13)

Some accidents have occurred throughout the world involving sealed radioactive sources (e.g. industrial radiography sources) which have been lost, mislaid or stolen. Removed from their shielding containers such sources can produce significant levels of external radiation and in a number of cases such accidents have caused some persons to be grossly irradiated and in a few cases deaths have resulted.

Within Australia a number of such accidents have occurred but none is known to have caused the deaths of persons accidentally irradiated.

Accidents Involving Nuclear Powered Warships

A large number of nuclear powered warships are in operation within the navies of countries such as the USA, the UK, the USSR and France. Nuclear powered warships are designed to have a high degree of reliability and safety, and have highly trained crews available to operate their nuclear reactors. There is no record of accidents to such vessels giving rise to release of radioactive materials to the environment such that harm may result to members of the public.

Nuclear powered warships of the US Navy have visited Australian ports on a number of occasions. A monitoring program is carried out during each visit and no infringement of public health radiation standards has ever been detected (14) (15) (16).

Accidents involving Aircraft carrying Nuclear Weapons

Nuclear weapons are designed so that it is necessary to actuate a specific sequence of positive arming actions before they are ready to produce a nuclear detonation[16]. In an accident (e.g. fire, aircraft crash etc) involving a nuclear weapon there will still be hazards associated with the conventional high explosives and fissile materials (e.g. plutonium, uranium etc.) contained within the weapon. The fissile material may be dispersed as small particles if the high explosive detonates or if the weapon is involved in a fire.

Australia does not possess nuclear weapons so no accidents of this type involving Australian aircraft can be envisaged.

A number of accidents involving US Air Force aircraft carrying nuclear weapons have occurred. Two of these accidents have been reported in open literature[17] [18] and are summarised below.

In January 1966 at Palomares, Spain, a collision and fire involved a B52 bomber and KC135 refuelling aircraft. Four thermonuclear bombs carried by the B52 were thrown loose: two fell with their parachutes open. One fell in the sea and one fell in the Almanzora River; both of these weapons were recovered intact. The other two weapons were not recovered intact as their parachutes did not open and the impact detonated the conventional high explosive they contained. The resulting fragmentation and oxidation of the uranium and plutonium in the weapons created a radioactive cloud which dispersed and was blown towards the sea by the strong prevailing wind. An extensive area was contaminated as the cloud settled on the ground, buildings and vegetation. The 'hottest' parts of the area were the two impact points, one a semi-desert hill 1500 metres SW of a village 72 metres above sea level on Algarrobones Hill and the other in market gardens at the extreme eastern edge of the village about 200 metres from the nearest houses. There was no external radiation hazard. Numerous contamination measurements were made of air, persons, crops, soil, water etc. The results showed no appreciable contamination on 1950 persons who were checked; urine samples showed that the quantity of plutonium inhaled represented no immediate risk. It was concluded that an area of approximately 116 hectares was contaminated by alpha emitters. Extensive decontamination operations were carried out in the area and radioactive residues were shipped in steel drums to the USA for disposal in the Savannah River Plant depository area.

In January 1968 at Thule, Greenland an in-flight fire occurred in a B52 bomber carrying four thermonuclear bombs (20 megatons) on a 24 hour airborne alert mission. The pilot notified the ground station of the fire situation, and requested permission for an immediate descent and emergency landing at Thule Air Base. Two minutes later the descent began and soon after all aircraft electrical power was lost and the bailout order was given and executed. The aircraft continued its descent, struck the ice intact in a steep left bank and disintegrated from impact, explosion and fire. The co-pilot was killed, the cause of his death being a head injury probably sustained when he left the aircraft. The other six crew members survived the ejection.

The ice at the point of impact was about 1 metre thick; the impact of the aircraft and detonation of the high explosive components of the nuclear weapon completely fractured and displaced the ice over an area of about $2100m^2$. Debris and fuel were spread over an area of approximately 700 x 150m and a fierce fire developed, lasting for more than 15 minutes. Because of these factors it was necessary to consider spread of plutonium to the atmosphere, to water and to ice and snow. Tritium contamination in the form of tritium oxide, was found on the surface largely confined to the blackened crust; the amount of tritium present was estimated at 50 TBq (1350 Ci) ± 50%.

Radiological surveys showed that the majority of the plutonium was confined to a limited area with contamination fixed to the debris. Monitoring teams, line abreast, picked up all smaller pieces of debris which were placed in containers. Large pieces were stacked, sprayed with water (which froze in the sub-zero temperatures) and secured against dispersion by storms.

About $12,000m^3$ of contaminated snow was removed and initially placed in 25,000 gallon tanks. A total of 67 such tanks were filled with contaminated snow and aircraft debris, and an additional four tanks with general contaminated debris (tyres, timber etc). Contaminated material was ultimately transported to the USA for disposal.

Many measurements were made on numerous samples during the course of this operation (known as Project Crested Ice) including ice cores, water, bottom samples from Bylot Sound, sewage, plankton and urine from personnel.

Conclusion

To date there have been no major radiological accidents in Australia. If adequate controls are maintained in all projects in Australia using significant amounts of ionising radiation and radioactive materials it is reasonable to assume that there is a low probability of such accidents occurring in the future.

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RADIOLOGICAL DEFENCE: REQUIREMENTS FOR RADIATION MEASUREMENT AND ASSESSMENT - SOME OVERSEAS ARRANGEMENTS

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Introduction

In this paper I will discuss the subject of radiological defence, that is, the provision of protective measures that would mitigate the effects of nuclear radiation in the event of a nuclear weapon attack. Although they are, of course, fundamental to the issues involved, evaluation of the probability of a nuclear attack, and assessment of the priority which should be assigned to defensive measures, are outside the scope of this paper. As a starting point, I will suppose that some measure of preparedness would be prudent, and go on from there to discuss matters relating to the establishment of a viable radiation measurement and assessment capability. Some material in the paper is derived from visits to civil defence centres in the USA, Canada and UK about 12 months ago.

Although the paper will concentrate on nuclear radiation problems, it should be stressed that it is important to take an overall, integrated approach, including blast, thermal radiation and electromagnetic pulse (EMP). Overseas, in the USA, Canada and UK, great importance is attached to the development and use of sophisticated damage-assessment models. A typical model, programmed for a computer, takes into account, for a specified threat situation, the weapon expected to be employed and its characteristics, and the detailed distribution of buildings and population. It calculates the damage and casualties due to all weapon effects, thereby providing much of the quantitative information essential for the planning of appropriate defensive measures, and post-attack relief and recovery.

In dealing with the nuclear radiations of a weapon it is important to distinguish between the initial radiations and the residual radiations. These are quite different in physical characteristics, and have characteristically different implications for civil defence. The initial radiations are the gamma and neutron radiations emitted within the first minute after the explosion. Like blast and thermal radiation, they may cause immediate or early casualties. The residual radiations consist mainly of gamma and beta radiations from radioactive fallout deposited on the ground some time after the explosion. They also include neutron-induced gamma-activity (NIGA) in environmental materials: however, NIGA is relatively unimportant, since it is localised near ground zero (GZ) within the zone of severe blast destruction.

The residual radiations give rise to a long term radiological hazard, which only gradually diminishes as the radioactive products decay.

In a related paper, to be given later in this Seminar, I will discuss RADIAC equipment. The acronym RADIAC refers to the rather specialised RADiation Indicating And Computing equipment which is required to detect and measure weapons radiation, and calculate its effects, either for civil defence or military purposes. This paper, and the other one, are intended to be complementary, and some cross-referencing is required. The second paper includes a discussion of radiation quantities, and their pre-SI and SI units of measurement. In this paper radiation values will be given in terms of the new SI units, with the corresponding pre-SI values and units following in parenthesis.

Radiation Injury and Exposure Control

Emergency civil defence planning is concerned with the nuclear radiations (both initial and residual types) because of their capacity to cause injury. To some extent these radiations may be compared to a poison: either a large single dose, or the accumulation of many small doses, can cause severe sickness or death, depending upon the size of the dose, and the state of health of the individual concerned. Where there is a succession of doses some recovery may take place between them, so that the effective total dose is less than the sum of the individual doses.

Some perspective as to the magnitude of the doses required to cause acute radiation effects is given by the following:

a. Radiation Sickness. This includes symptoms such as loss of appetite, nausea, fatigue, vomiting, and diarrhoea. As an example, the dose, VD_{50}, required to cause vomiting within 12 hours after exposure, in 50% of normal, healthy persons exposed to radiation, is about 2.7 Sv (270 rem).

b. Early (Within 60 days) Lethality. The median lethal dose, $LD_{50/60}$, required to cause death within 60 days after a single exposure, in 50% of normal, healthy persons exposed to radiation, is about 4.3 Sv (430 rem). Practically no deaths are expected for doses less than about 2 Sv (200 rem), and practically 100% deaths for doses greater than about 6 Sv (600 rem).

To assist in planning emergency operations all countries have prepared guides relating various levels of radiation effect to corresponding radiation doses. As an example, the "Penalty Table" prepared by the U.S. National Council on Radiation Protection and Measurements (1) is reproduced in Table 1. This table takes into account the period during which the radiation dose is accumulated, and makes an allowance for recovery processes. It was called a "Penalty Table" to emphasize that any assignment of personnel in emergency operations to one of the dose levels specified, would carry with it a corresponding risk of serious injury.

Initial Radiations

The weapon exploded at Hiroshima had an explosive yield of about 12.5 kt, and was exploded about 500 m above the ground on a clear day. Many Japanese were in the streets and unprotected. Most of the casualties were due to blast and thermal radiation. The initial radiations are estimated to have caused from 5% to 15% of the total number of early deaths.

However, if the weapon had been exploded closer to the ground, the initial radiations would have assumed greater importance. To see this, consider a blast overpressure of, say, 8 psi, and the initial radiation dose at the corresponding location, for different heights of burst. In the actual event this reference blast overpressure occurred at a distance of about 1280 m from GZ and over 50% of people inside houses died as a result of blast injuries. At this same distance the radiation dose inside the houses, allowing for shielding, was about 2 Sv (200 rem), which is less than that required to cause death (ref. Fig. 1 (a)). If the height of burst (HOB) had been 150 m, the reference blast overpressure of 8 psi would have occurred at about 880 m, and the radiation dose inside the houses at this distance would have been about 30 Sv (3000 rem) (ref. Fig. 1 (b)). If a near surface burst had been used, the corresponding distance and dose would have been about 760 m and 47 Sv (4700 rem) (ref. Fig. 1 (c)). It is evident from these calculations, which are based on nuclear effects data given by Glasstone and Dolan (2) and Kerr (3), that the proportion of initial radiation casualties would have been substantially increased, compared to the total number of casualties, had the explosion taken place at a low altitude. There is, of course, nothing to ensure that a low altitude burst will not occur in an attack, either deliberately, or as a result of some malfunction.

Over the years civil defence planning has not been concerned with the initial radiations, and has concentrated exclusively on the residual radiations. The reason for this is that attention has been focussed on a threat situation which involves employment of a relatively high-yield weapon, typically 1 Mt. With such a very high yield the initial radiations are contained within the large zone of severe blast effects, for all heights of burst, and are of no interest to civil defence.

However, with the introduction of multiple warhead weapons, which have component devices of relatively low yield, the situation is changed, and the initial radiations are being included in damage-assessment models developed overseas. As an example of what is possible today, the Russian SS-20 missile has three independently-targetable warheads, each with an explosive yield of about 150 kt. As another example, the missiles carried by the U.S. Trident submarines have eight independently-targetable warheads, each with an explosive yield of about 60 kt.

At the present time the initial radiations appear to have three main implications for radiological defence planning and emergency operations as follows:

a. They must be taken into account in emergency planning, along with blast, thermal radiation, and residual radiation, in assessments of the number of casualties.

b. They must be taken into account in shelter design. Existing shelter designs, based on protection against the residual radiations, may not be effective against the more penetrating initial radiations.

c. Provision should be made for determination of initial radiation doses, as well as residual radiation doses, if there is to be a proper basis for management of casualties and the exercise of radiation exposure control.

Residual Radiations

Because the weapon at Hiroshima was exploded high above the ground there was relatively little fallout, and no early deaths resulted from the residual radiations. For significant fallout to be produced the fireball must interact with the ground so that large amounts of debris are drawn up into the cloud, and relatively heavy particles are formed. These particles become contaminated with radioactive material, and fall to earth relatively quickly. They contaminate a large area of ground extending out from GZ in the direction of the prevailing wind, and give rise to a serious radiation hazard.

Typical idealised fallout dose-rate contour patterns are shown in Figs. 2(a), (b) and (c), for contact bursts of weapons with explosive yields of 500, 100 and 20 kt, respectively. In each case a uniform wind speed of 24 kmph (15 mph) has been assumed.

All dose-rate contours in Fig. 2 have been normalised to values, $\dot{D}_T$ Sv/h, at H+7 hours, that is, seven hours after the explosion. It should be understood that these dose-rates are notional ones, since fallout will not have arrived at all the points shown by this time. For example, for the 500 kt weapon (ref. Fig. 2(a)) fallout does not arrive at point A, until about H+17 hours. Similarly, for the other two weapons (ref. Figs. 2(b) and (c)), fallout does not arrive at the corresponding points A_2 and A_3 until about H+8 and H-1 hours, respectively. At these points A_1, A_2, and A_3

deposition of fallout is completed within a further period of about 30, 15 and 8 minutes, respectively.

Providing sufficient time has elapsed for the fall-out to be deposited, dose-rates, $\dot{D}(t)$ Sv/h, at any time H+t hours after the explosion, may be determined from the contours in Fig. 2 using the equation:

$$\dot{D}(t) = \dot{D}_T(t/7)^{-1.2} \quad (1)$$

For example, for the 500 kt weapon (ref. Fig. 2(a)), the dose-rate at point B at H+24 hours is $0.3\ (24/7)^{-1.2} = 70$ mSv/h (7 rem/h).

Because the dose-rates are not constant, but decay with time, doses received by individuals cannot be determined by simply multiplying the given dose-rate by the time duration of exposure. Using the standard $t^{-1.2}$ radioactive decay law for fission products, the dose, D Sv, received at any point, in any period, t hours, commencing from the time of explosion, is given by the equation:

$$D(t) = 52\ \dot{D}_7(t_{Arrival}^{-0.2} - t^{-0.2}) \quad (2)$$

where $t_{arrival}$ h is the time of arrival of the fallout.
For example, consider the 500 kt weapon (ref. Fig. 2(a)) and point B_1. Allowing for the 24 kmph wind, and a stabilised cloud radius of 6.4 km, deposition of fallout at this point occurs between about H+4.6 and H+5.2 hours, so that $t_{arrival}$ is about 5 hours. The dose received at point B_1 in the 24 hour period is therefore about

$$52\ .\ 0.3(5^{-0.2} - 24^{-0.2}) = 3.0 \text{ Sv (300 rem)},$$

which is sufficient to cause radiation sickness (ref. para. 2.2(a)). In a 2 day period the dose would accumulate to about 4.1 Sv (410 rem), which is about the median lethal dose (ref. para. 2.2(b)). Referring to the other weapons (ref. Figs. 2(b) and (c)), the corresponding 24 hour doses at points B_2 and B_3 are about 5.0 Sv (500 rem) and 7.0 Sv (700 rem), and the 2-day doses about 6.0 Sv (600 rem) and 8.1 Sv (810 rem), respectively.

Because the initial radiations are over within a period of only one minute after the explosion there is insufficient time for people to find a suitable protected position, unless there is pre-warning that a nuclear attack is imminent. It is, however, possible to mitigate the effects of fallout by exercise of appropriate radiation control after the explosion. Thus, providing the fallout pattern can be established quickly and reliably, the number of casualties can be significantly reduced by optimising movements within the contaminated area, relocating people, and/or using suitable shelters.

Figs. 3(a), (b), and (c) show actual fallout patterns measured in weapon tests. Due to the vagaries of the wind the last two deviate markedly from the idealised eliptical contours discussed above. All dose-rates in these figures are normalised to a time H+1 hours after the explosion. It will be noticed that the dose-rates in these examples are relatively low. This is because the weapons were exploded at a considerable height above the ground.

Three different methods that are available to determining the fallout pattern following a nuclear explosion are as follows:

a. Full Prediction Method. This method relies on elaborate theoretical modelling and uses a computer code. It is aimed at determining detailed fallout dose-rate contours, allowing for weapon parameters, wind speeds and direction at various altitudes, and particle size distribution. Because of the intrinsic difficulties in modelling fallout deposition from the cloud, and the uncertainties that would exist in the input data in any real event, the method is unsuitable for use in radiological defence.

b. Hazard-Zone Method. This is a much simplified method derived from the one above, and is aimed merely at determining two sector-shaped hazard-zones radiating out from GZ. As input data it requires weapon parameters and meteorological information. Different versions of the method have been developed overseas in the US and UK for civil defence and military use. However, because of the many simplifications and approximations made, and the large uncertainties that would exist in the input data, the method is generally regarded as unreliable. To emphasize this particular point I have taken weapon and meteorological data for two typical weapon tests which resulted in radioactive fallout, and have calculated the hazard-zones predicted by the procedure given in North Atlantic Treaty Organization STANAG 2103 (4). The same procedure is used by the Armies of US, Canada, UK and Australia for military purposes. The results are shown in Figs. 4 and 5. For comparison purposes the measured fallout dose-rate contours are also shown. In one example the width of the fallout is overestimated by the prediction method, and the length underestimated (ref. Fig. 4). In the other example the fallout is over-estimated (ref. Fig. 5). In calculating these hazard-zones wind speeds and directions measured at about the time of the explosions were used, and the directions of the predicted zones are nicely aligned with the actual fallout pattern. It is unlikely that this directional accuracy would be obtained in a nuclear attack situation, since

b. (continued)

up-to-date and accurate meteorological data may not be available. Another defect of the prediction method is that it cannot show the local variations in fallout intensity and hot spots which will occur in any real situation (ref. Fig. 3). For these reasons it is generally accepted overseas that hazard-zone prediction methods are of very limited use, and only serve to provide a preliminary, very tentative planning guide in emergency operations pending radiation measurements with RADIAC instruments. No emergency operations should be undertaken solely on the basis of predicted radiation levels.

c. RADIAC Measurement Method. This requires the availability of suitable RADIAC equipment capable of measuring the radiation dose-rate. Either hand-held, vehicular-mounted, or airborne RADIAC instruments may be used (see companion paper). Since it is based on hard measured data this is the most reliable method, and considerable priority must be attached to it.

Radiological Defence in the United Kingdom

The UK Warning and Monitoring Organization (UKWMO), which operates under the control of the Home Office, has the following functions:

a. Originate warnings to the public of impending air attack.

b. Provide confirmation of a nuclear strike.

c. Originate warnings to the public of the approach of radioactive fallout.

d. Provide government and armed service war HQs in the UK, offshore islands, and neighbouring countries with details of nuclear bursts and with a scientific appreciation of the path and intensity of fallout.

e. Provide an emergency meteorological service post-attack.

The UKWMO costs about £4 to 6 million/annum to maintain, and is staffed mainly by part-time volunteers from the Royal Observer Corps. Operated by a skeleton staff in peace-time it can be brought into full operation within a few hours.

Also under the control of the Home Office is a

Scientific Advisory Branch (SAB) concerned with scientific aspects of civil defence. It is supported by a volunteer-based organisation of about 70 Regional Scientific Advisers (RSAs) assigned to 10 civil defence regions covering the UK (ref. Fig. 6). These RSAs are senior personnel with professional qualifications. In each region one of the RSAs is nominated as the Chief Regional Scientific Advisor (CRSA). There is a Home Defence Scientific Advisory Committee which includes the ten CRSAs as members. Each regional HQ has, in addition to the CRSA and RSAs, a senior scientist appointed from the government scientific service, this person being designated as a Principal Scientific Advisor (PSA). The Home Defence Staff College at Easingwold, Yorkshire, operates training programs and exercises for government officials and emergency service personnel.

Air attacks on the UK would be detected by various systems including the Ballistic Missile Early Warning System (BMEWS) which has a point at Fylingdale near the Yorkshire coast, RAF Sector Operations Centres, NATO centres, and the North American Aerospace Defence Command (NORAD). Reports would be transmitted to the UK Regional Air Operations Centre (UKRAOC) for evaluation. The Home Office Principal Warning Officer stationed there can immediately issue an Attack Warning message to the BBC and to 250 Carrier Control points located at major police stations throughout the country including Scotland and Northern Ireland. These Carrier Control points would immediately issue warning messages to other police stations, civil and service HQs, service establishments, monitoring posts, fire stations, hospitals, and selected industrial centres. Some 19000 hand-operated sirens and/or maroons at these locations would be activated. The Carrier Control points would also activate some 8000 remotely operated power sirens located in densely populated areas. It is estimated that the entire population could be alerted by BBC warnings, and over 90% warned by the sirens and maroons. A warning time of 15 minutes is estimated.

The UK is divided into five approximately equal areas, or sectors, each with a Sector Control Post (ref. Fig. 7). The Metropolitan Sector includes the Greater London area and has a population of about 21 million, or about 2/5 of the total population. Each Sector is divided into five areas, each with a Group Control Post, the Sector Control Posts being co-located with one of their Group Control Posts. These Control Posts receive reports from a network of 873 Monitoring Posts distributed at about 10 mile intervals throughout the UK. All Control Posts are specially designed buildings to withstand blast and give protection against radioactive fallout. They are independent of mains services, being equipped with stand-by power. They have sanitation and ventilation facilities, and are provided with food and water supplies so that staff can survive for prolonged periods. They have several rooms for processing of data, staff accommodation, etc. Under full operational conditions Group and Sector Control Posts would be staffed by about 50 and 80 trained personnel, respectively. Monitoring Posts are much smaller, a typical one consisting of a concrete chamber about 7 x 16 feet x 7 feet high buried about 20 feet below ground level, with access through a vertical concrete shaft (ref. Fig. 8).

Each Monitoring Post has a communication link to its Group Control Post. In turn each Group Control Post has a communication link with its Sector Control Post. In addition there are communication links between adjacent Group Control Posts and between the five Sector Control Posts. In general, landlines are backed up by radio.

The various monitoring and control Posts are equipped with suitable RADIAC instruments which enable the position and height of burst of a weapon to be determined, and also its explosive yield (see companion paper). Following a nuclear attack the raw data from these instruments would be processed at the Group Control Posts. This information would be transmitted to neighbouring Group Control Posts, the Sector Control Posts, and civil and military HQs. The Group Control Posts would use the weapon data, together with meteorological data, to carry out a fallout prediction of the hazard-zone type. This is aimed at delineating the boundary within which the fallout would be contained during the first few hours after burst. Particular attention is paid to obtaining reliable meteorological data. The Sector Control Posts receive information from the Meteorological Office's £3 million computer installation at Bracknell, Berkshire, from eight Upper Air (Radio Sonde) Stations, and from 87 selected Monitoring Posts which take hourly surface weather observations using aneroid barometers (atmospheric pressure), handheld anemometers (wind speed and direction), and whirling frame psychrometers (temperature). Specially trained meteorologists at the Sector Control Posts analyse this information and issue reports and forecasts at least every 6 hours.

The various Monitoring and Control Posts are also equipped with suitable RADIAC survey meters which enable the dose-rates outside the Posts to be determined. As soon as fallout arrived at each Post the time-of-arrival would be recorded, and readings of dose-rate taken at regular five minute intervals. The direction and speed of travel of the fallout front is determined from the times-of-arrival at consecutive Posts. The survey meter readings indicate the width and intensity of the fallout field. Readings are plotted on large map overlays in the Group Control Posts. Results are transmitted to the Sector Control Posts. The UK is divided into 750 warning districts. Group Control Posts would warn a district 2 hours in advance if fallout was approaching it.

The Sector Control Posts coordinate the various activities and ensure the system is operating as required. They exchange information between themselves, and also communicate with corresponding centres in NATO countries.

For example, the Metropolitan Sector Post that I visited is set up to exchange information on nuclear bursts and fallout with France and Belgium.

Radiological Defence in the United States and Canada

These two countries are included together here since they both employ the Radiological Defence (RADEF) system of radiation monitoring and reporting. In the US the responsibility for establishing and maintaining a national emergency management capability rests with the Federal Emergency Management Agency (FEMA). In Canada it rests with Emergency Planning Canada (EPC). Both FEMA and EPC are concerned with natural disasters as well as nuclear attacks involving the civilian population. By comparison, SAB in the UK is only concerned with the latter.

Should the North American Aerospace Defence Command (NORAD) at Cheyenne Mountain, Colorado, detect an attack on North America it would alert authorities in both the US and Canada. Both countries have adopted the same warning signal, and provision is made for warning emergency centres and the population as required. For example, in Canada, there are some 1700 sirens across the country. Emergency attack warning messages and survival instructions for the public have been pre-recorded in both official languages. Circuits are tested regularly. The warning system is not maintained in full operational capability, but can be rapidly developed if required. It is estimated that at least 95% of the Canadian population would be alerted if an attack occurred.

In Canada the RADEF system is the responsibility of the Department of National Defence. It involves a network of Monitoring Stations at selected locations covering all populated areas. These Monitoring Stations report to Municipal Emergency Government HQs (MEGHQs). Higher control is exercised at Region and Zone Emergency Government HQs (REGHQs and ZEGHQs). The density and siting of the Monitoring Stations is based on population and land area: for example, a typical municipality with a population of about 20,000 would have 9 Monitoring Stations. Personnel manning the Monitoring Stations are called Monitors, generally two per Station. Each HQ has a radiological staff, the principal member being called a Radiological Adviser or Radiological Defence Officer. The Monitoring Stations are organised, equipped and sited by the municipalities. The Monitors are trained by the municipalities. Training of the Radiological Defence Officers is conducted at the Federal Study Centre, Arnprior, Ontario.

In the US the RADEF system is the responsibility of FEMA. A network of Monitoring Stations is distributed across the country. Local and State Emergency Operating Centres (EOCs) are set up as central facilities from which key personnel can coordinate and control the operation of emergency forces. The EOCs are subdivided into lower echelon

Zone Control Centres. The system employs Monitors and Radiological Defence Officers as in the Canadian system. As in Canada the Monitoring Stations are organised, equipped and sited by local authorities. Monitors are also trained by these authorities. Training of the Radiological Defence Officers is conducted at establishments operated by FEMA.

An important difference between the RADEF system and the UKWMO system is that the former makes no provision for fallout prediction, but relies on measured radiation dose-rates. Thus, in both the US and Canada, the Monitoring Stations are not equipped with RADIAC instruments suitable for determining weapon parameters such as the location of the explosion, or its explosive yield. RADIAC instruments are limited to those necessary for radiation measurement (see companion paper).

Radiation dose-rate headings obtained by the Monitors are transmitted to Control Posts for analysis, and plotting on map overlays. Information is transmitted to higher echelons of control as required. Protective measures may range from complete release of the public from shelters when radiation is sufficiently low, to remedial evacuation of the public when it is unacceptably high. In addition to recording radiation dose-rate at the Monitoring Stations, Monitors in Canada are required to leave their Stations, after the radiation intensity has decayed to a relatively safe level, and record radiation dose-rates along predetermined routes.

Summary

A major argument advanced in this paper is that many issues in radiological defence can only be resolved by undertaking realistic damage-assessment studies, taking into account all weapon effects, and the distribution of buildings and population in the threatened areas. Sophisticated damage-assessment models for this purpose have been developed overseas.

Nuclear radiation cannot be detected by the human senses of sight, hearing, touch or taste. If it is accepted that a nuclear threat exists, then, for protective purposes, a viable radiation measurement and assessment capability must be considered essential. In the absence of such a capability it would not be possible to exercise effective radiation exposure control, and many needless casualties would inevitably result.

Taking into account the various issues discussed in this paper, a number of broad requirements for a viable radiation measuring and assessment capability may be formulated. These are as follows:

99.

a. <u>Establishment of a Network of Monitoring Stations and a Hierarchy of Operational and Control Stations</u>. These Stations should be strategically sited in relation to regions where there is a threat of nuclear attack.

b. <u>Provision of Suitable RADIAC Equipment</u>. This equipment needs to be maintained in operational order, and to be readily available in an emergency. Appropriate equipment should be assigned to monitoring stations and emergency services. Some equipment may be stockpiled.

c. <u>Availability of Suitably Trained Personnel</u>. Appropriate training courses are required. Since it may be difficult to maintain operational capability over long periods of non-use, a system of refresher courses may be useful.

d. <u>Clear Definition of the Responsibilities of Participating Authorities</u>. This is, of course, essential to good management and emergency operations.

e. <u>Allocation of Appropriate Funds and Resources</u>. This is dependent upon policy decisions.

Some relevant questions are as follows:

a. How many Monitoring Stations, etc., and where should they be sited?

b. What types of RADIAC equipment are required, and how many? How should this equipment be distributed? Who would be responsible for its maintenance?

c. How many trained personnel are required? What level of training is required?

d. Who is responsible for what?

e. What are the resource constraints?

Finally, attention is drawn to two options which exist in finally deciding upon a radiological defence system. These options are as follows:

a. Fully Operational System.

b. Standby System.

The Standby System has the advantage of relatively low initial and maintenance costs in the pre-emergency period. It must be capable of rapid development in a crisis, so as to maximise saving of lives. This means that there must be detailed planning at all levels. The Standby System may be cost-effective in the Australian situation.

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1. "Radiological Factors Affecting Decision-Making in a Nuclear Attack" (1974). NCRP Report No. 42, National Council on Radiation Protection and Measurements, Washington DC.

2. "The Effects of Nuclear Weapons" (1977). Glasstone, S, and Dolan, P, Eds., Third Edition, 1977, US Department of Defence.

3. Kerr, GD (1979). "Organ Dose Estimates for the Japanese Atomic-Bomb Survivors", Health Physics, 37, 487-508.

4. North Atlantic Treaty Organization Standardization Agreement, STANAG 2103, Edition No 4, (1978).

TABLE 1 - THE "PENALTY TABLE" OF NCRP 42 (ref. 1)

Medical care will be needed by	Accumulated Radiation Exposure (R) in any period of		
	1 week	1 month	4 months
None	150	200	300
Some (5% may die)	250	350	500
Most (50% may die)	450	600	-

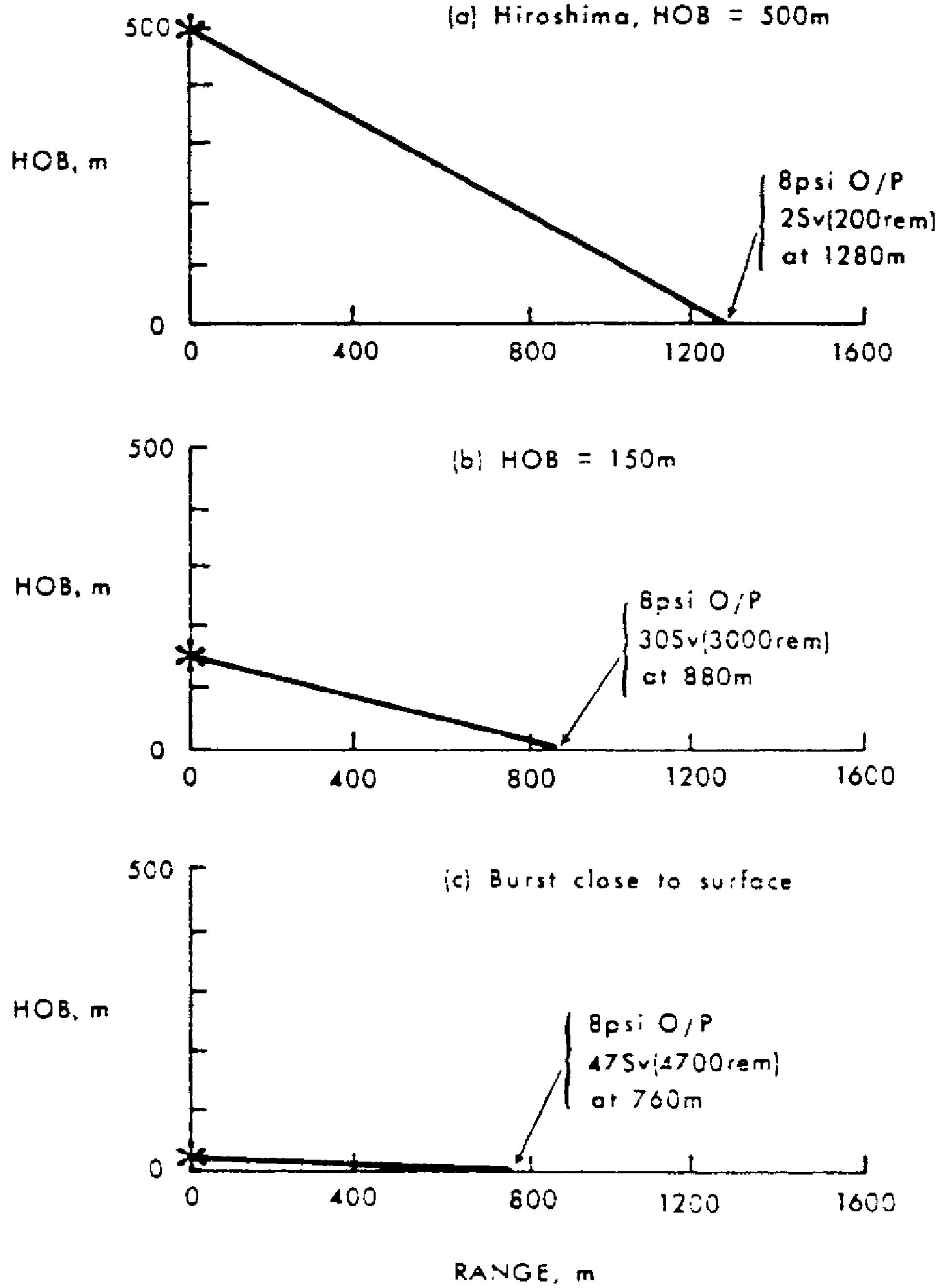

FIG. 1. INFLUENCE OF HEIGHT OF BURST (HOB) ON RELATIVE IMPORTANCE OF INITIAL RADIATIONS AND BLAST

Weapon Yield 12.5 kt
Radiation Doses are inside Japanese houses at Hiroshima

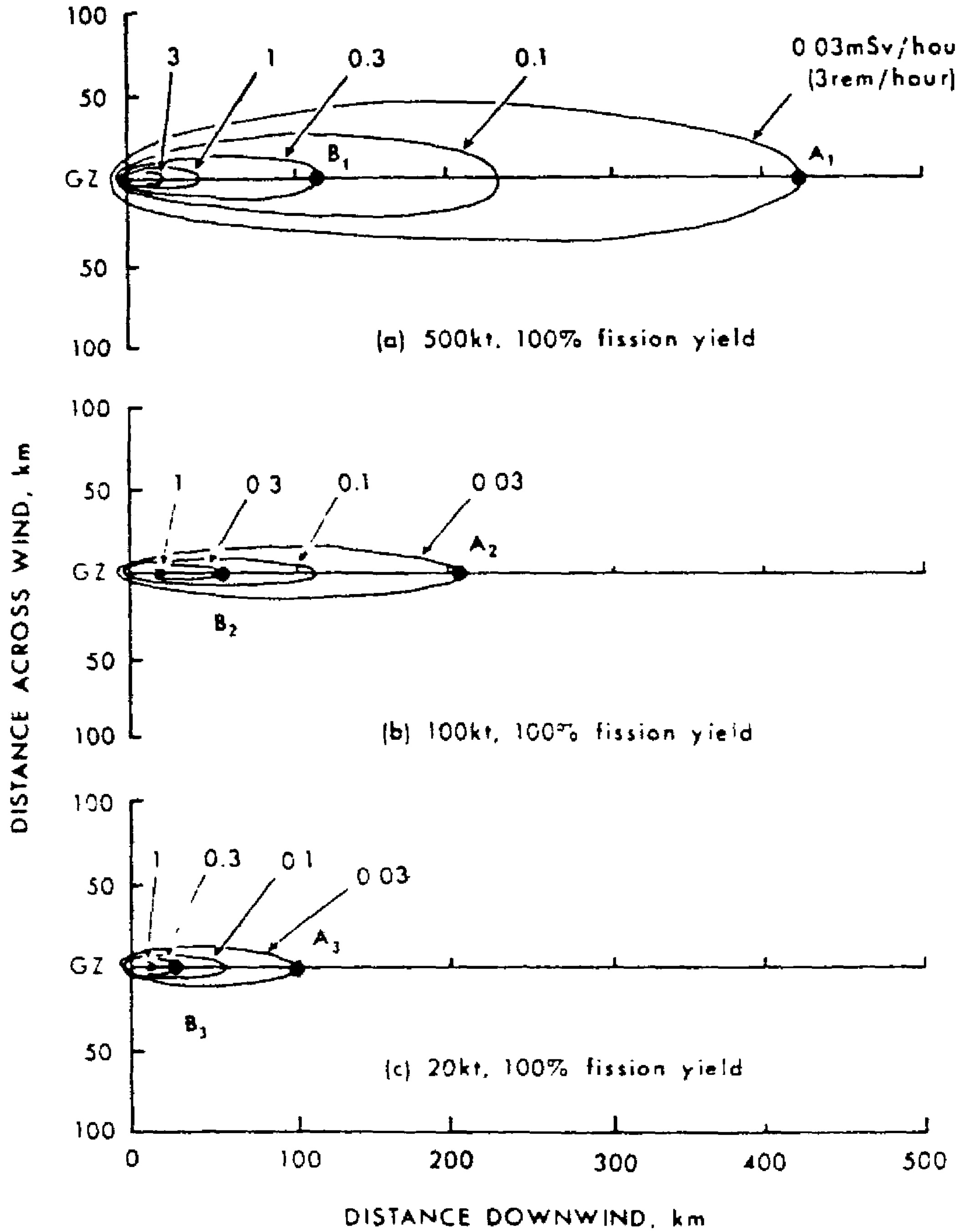

FIG. 2. IDEALIZED FALLOUT DOSE-RATE CONTOURS AT H-7 HOURS FOR VARIOUS CONTACT BURSTS

Wind Speed 24 kmph (15 mph)

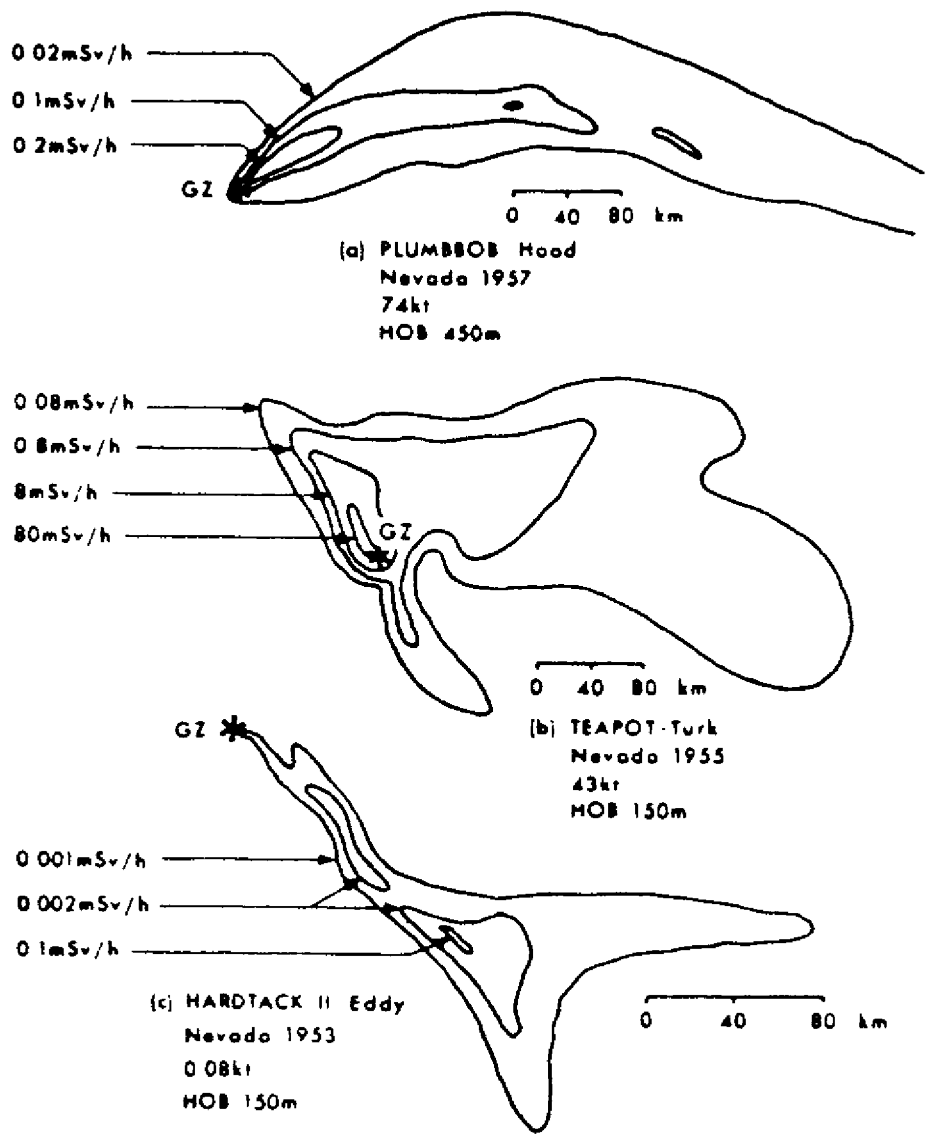

FIG. 3 REAL FALLOUT DOSE-RATES CONTOURS AT H + 1 HOURS

The TEAPOT-TURK weapon had a smaller yield than the PLUMBBOB-HOOD one, but fallout dose-rates are much greater due to the lower yield.

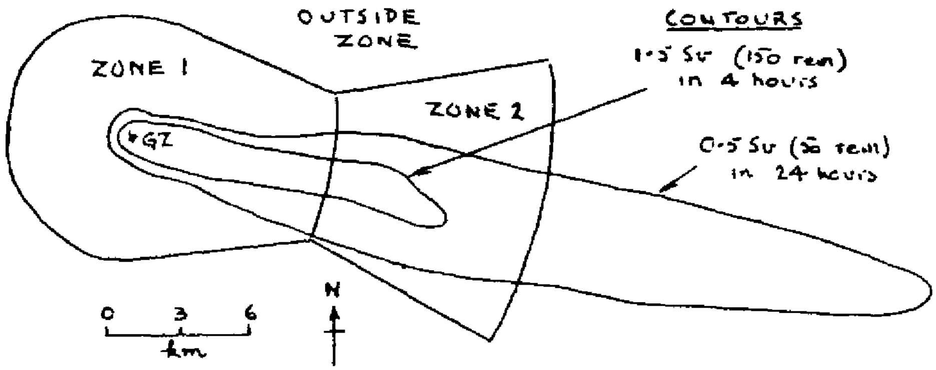

FIG. 4. OPERATION UPSHOT-KNOTHOLE - SIMON (1953)
43 kt, 300 feet above ground

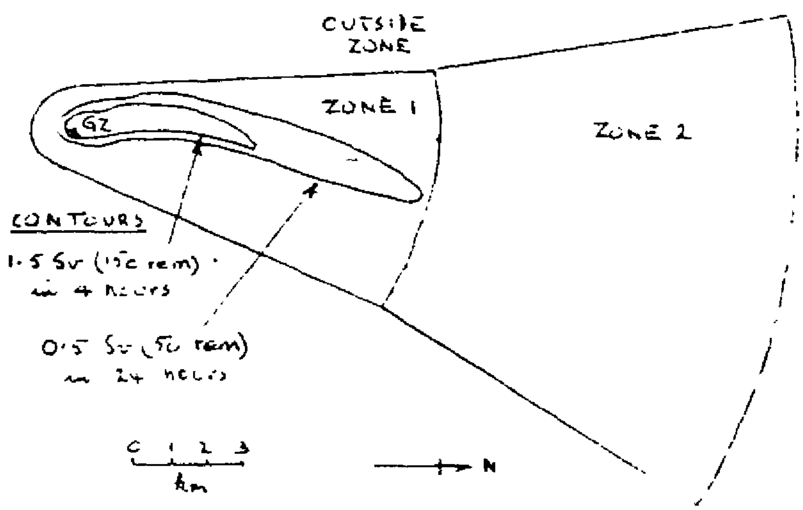

FIG 5 OPERATION BUSTER-JANGLE - SUGAR (1951)
1.2 kt, 3.5 feet above ground

DEFINITIONS OF HAZARD-ZONES:

INSIDE ZONE 1	Possibly 150R or more in 4 hours
INSIDE ZONE 2	Less than 150R in 4 hours. Possibly 50R or more in 24 hours.
OUTSIDE ZONES 1 & 2	Less than 50R in 24 hours Less than 150R for infinite stay.

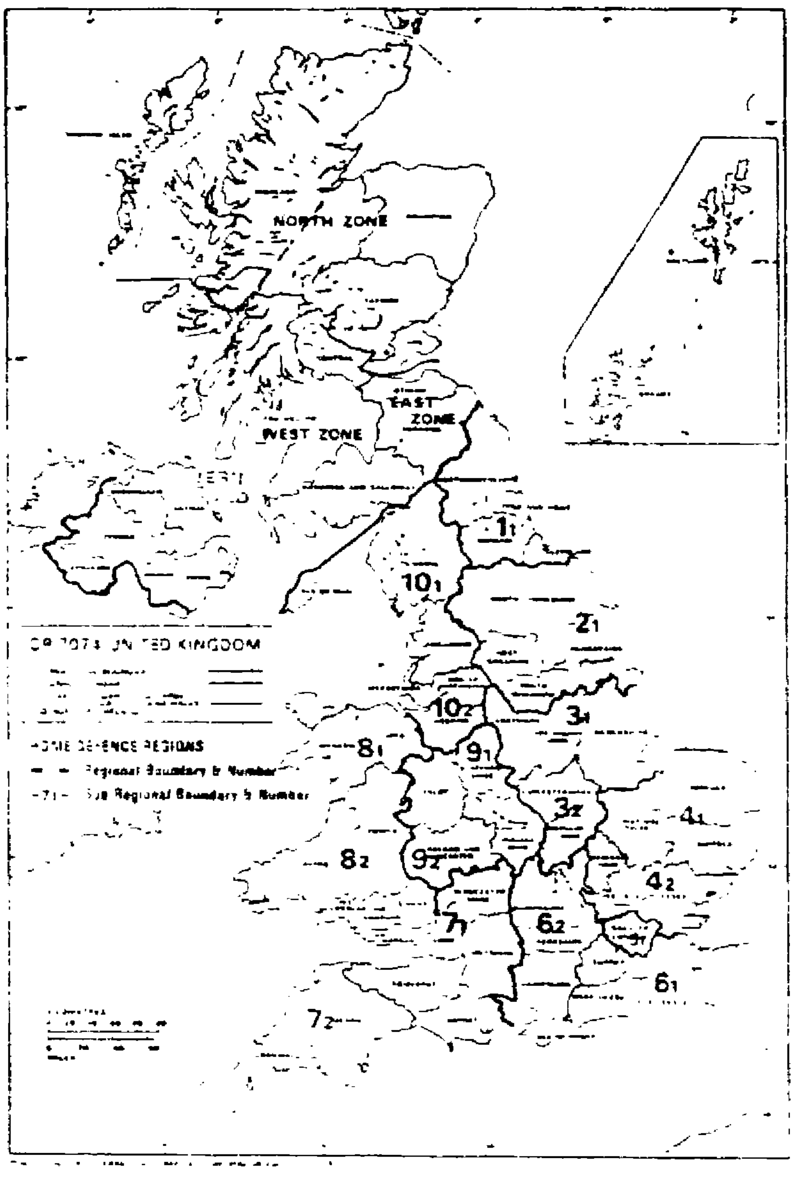

FIG. 6. HOME DEFENCE REGIONS IN THE UNITED KINGDOM

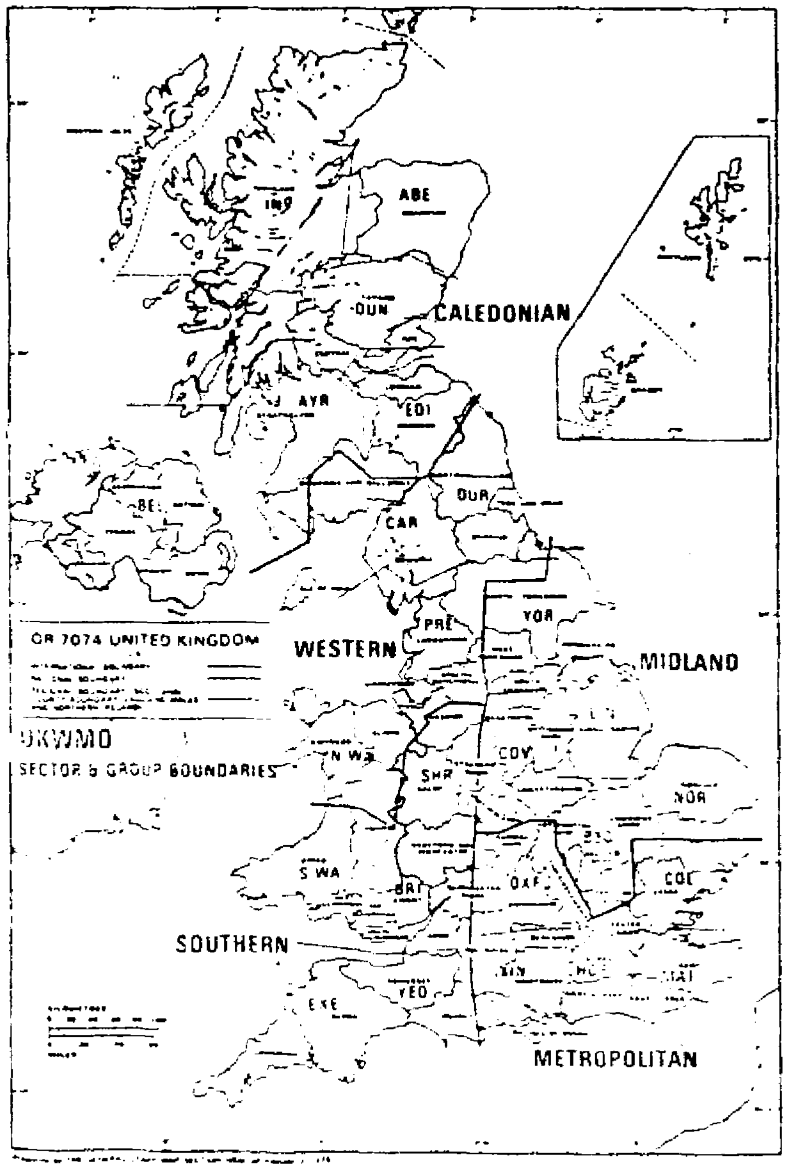

FIG. 7. UNITED KINGDOM WARNING AND MONITORING ORGANIZATION (UKWMO) SECTOR AND GROUP BOUNDARIES

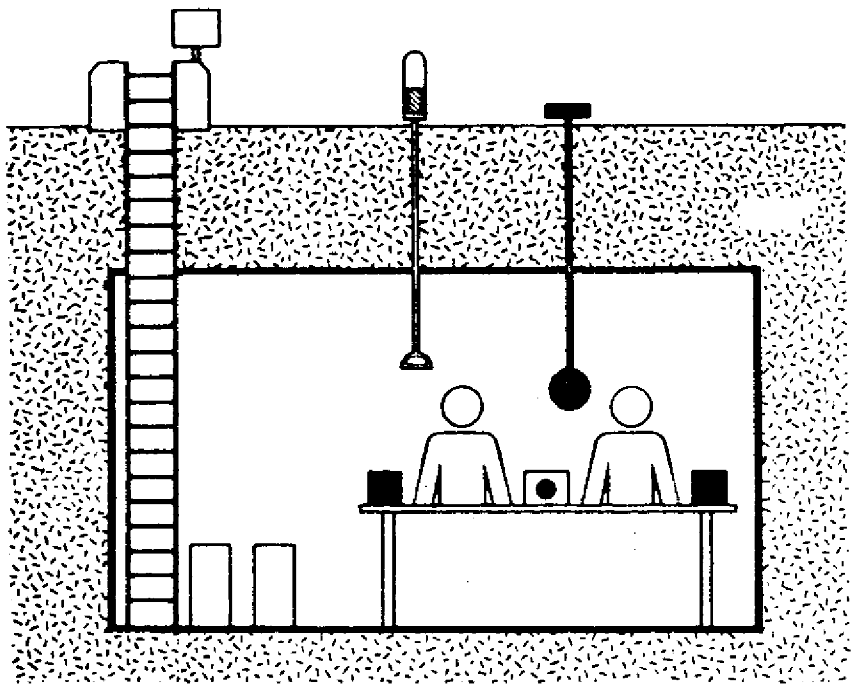

FIG. 8. TYPICAL MONITORING POST IN THE UNITED KINDOM.