ROSYTH PUBLIC SAFETY SCHEME
(ROSPUBSAFE)

PART I - GENERAL INFORMATION

1.1 REACTOR OPERATION

1.1.1 A Nuclear Powered Warship uses conventional steam turbine machinery for propulsion. The supply of steam for this machinery comes from a nuclear reactor plant instead of an oil-fired boiler. The nuclear reactor is therefore a heat source which is designed to generate steam, replacing the furnace of a conventional boiler. The nuclear reactor and associated plant are contained in a separate reactor compartment within the warship.

1.1.2 A nuclear reactor core is made up of fuel elements and control rods. To achieve criticality, selected control rods are slowly withdrawn from the core until the process of nuclear fission becomes self-sustaining. The reactor can then be operated to produce useful power. Nuclear fission generates heat which would melt the fuel elements if they were not cooled. The heat is removed from the core by the primary coolant water system and is transferred, in the boilers, to the secondary system where the steam so produced is used to drive the propulsion system and other auxiliary machinery. The cooled primary coolant water is then recycled through the reactor core.

1.2 REACTOR CONTAINMENT

1.2.1 Nuclear fission also produces radioactive fission products which emit radiations potentially hazardous to health. There is no hazard provided the fission products remain within the fuel elements, each of which is enclosed by a strong outer metallic case, or cladding.

1.2.2 Should the cladding fail and the primary coolant water become contaminated with fission products, the coolant system, which is itself leakproof, would contain the release and prevent its further spread.

1.2.3 In the unlikely event of a large uncontrolled primary coolant leak caused, for example, by pipe failure, the fuel cladding would overheat and eventually melt, thus releasing radioactive fission products into the compartment containing the reactor and its associated primary coolant systems. The worst accident of this type is termed the Maximum Design Accident (MDA), and is often referred to as the Contained Accident.

1.2.4 The reactor compartment itself is designed and constructed to provide primary containment and to withstand the severe pressure rises associated with the Maximum Design Accident. Though this containment is expected to remain intact, the presence of a small leak could result in a very slow release to the remainder of the boat and thence to the outside atmosphere, of a fraction of the fission products discharged into the reactor compartment. An even less likely accident is the sudden and complete failure of the primary coolanty system concurrent with a breach of the primary containment. There would then be a short-term release to the outside atmosphere of a much greater proportion of the fission products. This is termed the Primary Containment Failure Accident (PCFA), and is often referred to as the Uncontained Accident.

1.2.5 In order to reduce the probability of fission products escaping to the outside atmosphere, in the remote event of failure of the internal bulkheads forming part of primary containment, the adjacent compartments are designed to form yet another barrier known as secondary containment.

1.3 REACTOR SHIELDING

1.3.1 Within the reactor compartment, most of the radiation shielding is concentrated around the reactor core. The remainder is built into the reactor compartment boundary, principally to reduce gamma radiation from primary systems during normal operation to a level acceptable to the warship crew. In the event of a major release of fission products into the primary systems, the boundary shielding would no longer reduce radiation intensities to insignificant levels.

1.4 REACTOR ACCIDENT

1.4.1 A reactor accident is defined as an unexpected event involving a nuclear reactor plant which is likely to lead to or has resulted in a radiological hazard external to the reactor plant.

1.4.2 It is impossible for a reactor accident to result in an atomic-bomb type explosion, and the design, construction and operation of reactor plants are extremely carefully supervised and controlled to reduce the risk of any other form of accident to the absolute minimum.

1.4.3 Nevertheless, there is a very remote possibility of a sudden and complete failure of the primary coolant water system. For this to happen, it would be necessary for the major component of the primary circuit to fracture completely, so that all the primary coolant water escaped into the reactor compartment. If the reactor core could no longer be cooled, the fuel elements would melt and the fission products would be released into the reactor containment.

1.4.4 Although the reactor compartment is designed to withstand the high rise in pressure which results from a catastrophic failure of the primary coolant system, it is penetrated by numerous pipes and cables. In the event of an accident these penetrations may develop leaks.

1.4.5 A massive disruptiuon of the reactor compartment from, for example, a collision would almost certainly sink the warship but the release of fission products to the sea would be insignificant unless the primary circuit and containment are breached and core meltdown occurs; even in these latter circumstances, release to the atmosphere would be minimal

1.5 REACTOR ACCIDENT PROBABILITIES

1.5.1 Reactor accident probabilities consider the possible occurrence of the reactor accident and the probable magnitude of any release to the atmosphere.

1.5.2 The Maximum Design Accident (Para 1.2.3) may result in a release from the primary containment to secondary containment up to 40 TBq (1000 Curies) of Iodine 131, together with up to 4 PBq (100,000 Curies) of other volatile and gaseous fission products over a period of 24 hours; the probability of this accident occurring is predicted at about once in 10,000 years of reactor operation. Secondary containment procedures ensure that only a small proportion of this release will reach atmosphere.

1.5.3 The Primary Containment Failure Accident (Para 1.2.4) may result in a release from warship to the atmosphere of up to 4 PBq (100,000 Curies) of Iodine 131, together with 400 PBq (10,000,000 Curies) of other volatile and gaseous fission products within one hour. The probability of this accident occurring is predicted at about once in 1,000,000 years of reactor operation.

1.5.4 It can be seen that the probability of the Primary Containment Failure Accident occurring is 100 times less than for the Maximum Design Accident, but there is no method of predicting when either accident is likely to occur. A reactor accident, although highly unlikely, could happen at any time during the operation of a reactor. An accident could occur at times other than when the reactor is operating, and this possibility should not be discounted.

1.6 THE RADIATION HAZARDS

1.6.1 The fission products which remain within the reactor compartment containment after an accident are a source of intense gamma radiation which is transmitted through the warship's hull in all directions. the intensity of gamma radiation is rapidly reduced by both distance and shielding, but excessive radiation doses could be acquired by personnel who do not evacuate immediately from points within the close vicinity of the warship.

1.6.2 Only if the fission products are released to atmosphere will they present any significant hazard, in the form of a radioactive 'cloud', to persons further away and downwind of the accident.

1.6.3 There are five ways in which people can be irradiated following a release of fission products to atmosphere:

a. By direct gamma radiation from the cloud as it passes by.

b. By inhaling radioactive fission products from the cloud. Radioactive iodine is readily absorbed by the body and is concentrated by the thyroid gland. As a result of the irradiation of the thyroid tissue, thyroid cancer may develop several years later unless countermeasures are taken to reduce the thyroid uptake of radioactive iodine. The radiation levels necessary to produce this effect are fairly high and are unlikely to occur in persons exposed to the cloud when they are at distances of greater than 550 metres from the warship. The distance of 550 metres is known as the evacuation distance. The thyroid absorption of radioactive iodine can be substantially reduced by saturating the thyroid gland with natural iodine, through taking Potassium Iodate Tablets.

c. By gamma radiation from fission products deposited on the ground. This route, like a., results in a fairly uniform radiation dose throughout the body, and could eventually result in cancer.

d. By inhalation of radioactivity resuspended from the ground. For fission products, this route has been shown to be insignificant compared with b. and c.

e. By eating food or drinking milk or water which have been contaminated by fission products. At distances greater than one kilometre from the submarine, contamination of exposed food or drinking water is insignificant, but it is possible that milk produced by dairy cows and goats grazing on contaminated pasture several kilometres downwind of the accident could be contaminated with radioactive iodine, and constitute a hazard therefore to the thyroid glands of those who drink it.

1.7 PROTECTION AGAINST THE HAZARDS

1.7.1 As a general principle, the greater the radiation dose, the higher the risks. The National Radiological Protection Board (NRPB) is tasked with giving advice on the hazards to health from radiation, and in 1981 updated advice to HM Government on criteria for limiting doses to the public in the event of accidental exposure to radiation. (NRPB Report ERL2).

1.7.2 The NRPB advice consists essentially of identifying a range of doses, known as upper and lower Emergency Reference Levels (ERL's) against which consideration should be given to taking specified countermeasures. As the risks associated with each countermeasure are different it follows that the risk to any individual from a given countermeasure is dependent on the affected site, the type of installation concerned and conditions at the time of the accident. At the lower end of the range, NRPB consider the risks associated with the countermeasure greater than those associated with the radiation dose. At the upper end of the range, NRPB expects the countermeasure to be introduced whatever the circumstances. There are three countermeasures recommended by NRPB as appropriate to the first 12 hours after the accident:

a. Sheltering, or staying indoors with doors and windows shut.

b. Stable Iodine. If stable (non-radioactive) iodine, in the form of Potassium Iodate Tablets, is taken within a few hours of the inhalation of radioactive iodine, the vast excess of stable iodine will substantially reduce the radiation dose to the thyroid gland.

c. Evacuation protects predominantly against radiation from fission products deposited on the ground.

NRPB consider that other countermeasures such as decontamination of buildings should be implemented only after the extent of these problems have been evaluated.

1.7.3 To ensure similar standards of protection at all nuclear submarine berths the Ministry of Defence have adopted an Emergency Action Guidance Level (EAGL) for each countermeasure (as shown in the following table) at which implementation of the countermeasure would be advised.

EMERGENCY ACTION GUIDANCE LEVELS (EAGL's)

Countermeasure	Dose Equivalent Level (mSv)	
	Whole Body	Single Organ
Evacuation	100	300
Sheltering	25	250
Stable Iodine	-	50

NOTE: EAGL's are the selected values from within the range of ERL's (see paragraph 1.7.2) which are appropriate to nuclear submarine reactor accidents.

1.8 EXTENT OF THE HAZARD AND RELATIONSHIP WITH ERL's/EAGL's

1.8.1 There are four zones around the submarine which can be described in terms of the radiation doses people in them could receive after a reactor accident:

a. The Exclusion Area comprising the submarine and a small area, of the adjacent berth where, whatever countermeasures are taken, individuals within may still exceed one or more of the upper level ERLs.

b. The Evacuation Distance (550 meters) is the radius of a circular zone centred on the submarine. In this zone, countermeasures are taken automatically as soon as a reactor accident occurs, and all people within the zone have been given instructions on what they should do in the event of an accident. Provided they follow these instructions, no people within the Evacuation Distance (but outside the Exclusion Area) should exceed any of the upper level ERLs, and the majority will not exceed any of the lower level ERLs. (NB: At Rosyth the Exacuation Distance is contained within the Boundary Fence of the Naval Base).

c. Outside the Evacuation Distance (ie 550 metres or more from the submarine), following the Maximum Design Accident, no countermeasures are required to prevent individuals exceeding the upper level ERLs, even for those directly downwind. Following the much less likely Primary Containment Failure Accident, countermeasures may be required in the downwind sector.

d. The 'No-hazard' Distance The probability that any individual more than 10 km diownwind could exceed any of the upper level ERLs is so remote that there is no requirement for any accident pre-planning outside that distance.

1.8.2 For the purposes of contingency planning, it is Ministry of Defence policy to assume that all accidents have consequences as severe as the Maximum Design Accident. This will almost always be pessimistic, but nevertheless, automatic arrangements are made as follows:

a. Within the Exclusion Area all individuals are accounted for, and carry accident dosemeters AT ALL TIMES. In the event of an accident, all are regarded as having exceeded the upper level ERLs until evaluation of the dose they actually received shows this not to be the case. These evaluations would be undertaken rapidly using locally available equipment.

b. Within the Evacuation Distance all non-essential individuals are either evacuated as soon as the accident occurs by pre-planned routes, or sheltered prior to subsequent planned evacuation. All are given stable iodine (Potassium Iodate) as soon as possible, and are asked to record where they were and what they did when they heard the accident alarm. A small number of key personnel may remain in or re-enter this zone, but only if essential, after taking stable iodine, and, where appropriate, wearing protective clothing.

c. Outside the Evacuation Distance monitoring for airborne and deposited activity follows a pre-arranged plan. If results suggest that the appropriate EAGL's and countermeasures should be invoked, the affected area(s) will be delineated. Since this situation can only result from the Primary Containment Failure Accident which has to result in a rapid release of short duration (para 1.2.4), sheltering is not considered to be an appropriate automatic countermeasure, because the hazard will have passed before the people can be warned. However, the reduction in dose resulting from the administration of stable iodine does mean that the impracticability of using sheltering as a countermeasure is unlikely to result in many people exceeding the sheltering EAGL. Subsequent monitoring effort is devoted to aiding a decision on the need for evacuation as a result of fission products deposited on the ground. Finally, assessment of exposed and growing foods will be required to confirm whether the ban on their consumption already advised by the appropriate authorities need be continued or revised.

d. Outside the No-hazard Distance Contamination levels on pasture will be very low, and of no direct hazard to man. However, cows and goats are very efficient grazers and can cover a considerable area of land each day. Iodine is in short supply in nature, and therefore they concentrate it in their milk to provide adequate amounts for their young. At least twenty-four hours will elapse before the predominant radioactive species appears in milk. Based on monitoring results, appropriate authorities may recommend a ban on the consumption of milk from the affected area.

1.9 BERTHING AND MONITORING POLICY

1.9.1 Because there must be an effective evacuation of persons to outside the 550 metres Evacuation distance, the berths for nuclear warships are carefully chosen so that few members of the General Public live within this distance. Special care is also taken to ensure that the berths are sited as far away as is practicable from schools, hospitals and other public utilities.

1.9.2 Possible navigational hazards in the approaches to the berths are also considered and precautionary measures (eg the provision of tugs) are taken to prevent collision and stranding.

1.9.3 Berths approved for Nuclear Powered Warships are categorised X or Z depending on whether they will be used for building, refitting, repairing or for operational, rest and recreational purposes.

a. At X Berths

At Naval Bases with X berths there is a health physics department which is responsible for the radiological safety of routine operations. At Rosyth, the staff and facilities of the health physics department form the Local Emergency Monitoring Organisation (LEMO), Rosyth.

b. At Z Berths

At Z berths in Scotland, other than those in HM Naval Base, Rosyth, NEMO Scotland may be deployed to provide a local monitoring capability for the duration of an NPW visit.

1.10 SAFETY SCHEMES

1.10.1 Port Admiral, Rosyth, is responsible for issuing Nuclear Safety (NUSAFE) Orders for the protection of personnel within the Naval Base.

1.10.2 At category X berths, Flag Officer Scotland and Northern Ireland and the Civil Authorities form a Local Liaison Committee (LLC) which has the responsibility of reassuring local opinion on the hazards involved, of conveying to the public the significance of any accidents and of creating the administrative machinery for the protection of the population in the event of a serious accident. To these ends a Public Safety Scheme is prepared by Flag Officer Scotland and Northern Ireland in consultation with the local Civil Authorities.

1.11 THE NAVAL EMERGENCY MONITORING ORGANISATION (NEMO)

1.11.1 The Chairman Naval Nuclear Technical Safety Panel exercises functional responsibility, through the Inspector NEMO, for the Naval Emergency Monitoring Organisation which consists of:

a. The Naval Emergency Monitoring Team (NEMT))NEMT and DRPS
)together form a

b. Defence Radiological Protection Service (DRPS))NEMO Team.

c. Local Emergency Monitoring Organisation (LEMO) (formed from staff and facilities of the Health Physics Department at category X berths).

d. NEMO Scotland based at the Clyde Area Monitoring Headquarters, Rhu, Dunbartonshire.

NEMO Headquarters is based at the Institute of Naval Medicine, Alverstoke, Gosport, Hampshire, PO12 2DL.

1.11.2 For visits of nuclear powered warships to category Z berths in Scotland, NEMO, Scotland, based at Faslane, is at one hour's notice and will be deployed if there is an accident at Rosyth.

1.11.3 In the event of a nuclear reactor accident, naval medical officers and civilian health physicists from the Defence Radiological Protection Service (DRPS) will deploy to the scene as soon as possible. A back-up Naval Emergency Monitoring Team, if required will be mobilised and deployed from Alverstoke to an accident at Rosyth.

1.11.4 Before approval is given for a nuclear powered warship to visit a category Z berth, CNNTSP must be satisfied that the arrangements contained in the appropriate safety orders can provide the necessary protection for the General Public, and can be implemented satisfactorily. He must also be satisfied that the appropriate facilities (eg a Nuclear Accident Headquarters) and information (eg Meteorological Reports) will be available.