Policy Statement on Claims for Ionising Radiation Related Conditions
Summary

The Department's normal policy is that:-

1. In general an award of war pension will be considered in any case where there is reliable evidence of service related ionising radiation exposure **and** there is a recognised causal link between the claimed condition and such exposure.

2. The Secretary of State does not accept, as a matter of course, that those present at UK atmospheric nuclear test detonations and clean up operations were exposed to harmful levels of ionising radiation as a result of service in these locations in the armed forces.

3. **Service related ionising radiation exposure** means exposure to a measurable level of ionising radiation due to service in the armed forces and as determined by radiological dosimetry specialist report.

4. Awards can be made for leukaemia (other than chronic lymphatic leukaemia) and primary polycythaemia rubra vera if their clinical onset is within 25 years of first visiting the sites, based on **presence only** at the tests (ie exposure to service-related ionising radiation does not need to be shown).

5. Present overall evidence does not raise a reasonable doubt that ionising radiation causes atherosclerosis or related coronary heart diseases.

6. A Glossary setting out some key technical terms is found at the end of this policy statement.

The Purpose

7. This statement sets out the Department's policy on deciding claims for war pensions where service related ionising radiation exposure is alleged to have caused disablement or death. It also states the reasoning and evidence on which the policy is based. Situations where claims covered by the policy would be expected to arise include:

- participation in the UK nuclear tests in the Pacific and Australia or as a result of the subsequent clean up operations at the test sites
- Prisoners of War held in Nagasaki or Hiroshima during WWII and the subsequent clean up operations
- accidents on board nuclear submarines or ships
- handling nuclear weapons
- employment as a radiographer or other medic eg where X-ray equipment is in use

About 27,000 UK servicemen participated in the UK nuclear tests and the largest number of claims relate to presence at the nuclear test sites. Because the effects of excess ionising radiation can take a long time to become apparent most claims are made under Article 5 of the Service Pensions Order (1983).

The Law - How the scheme works

8. A war pension may be claimed for any disablement by anyone who has served in the British Armed Forces. Claims may be made at any time from service release. Decisions are evidence based and each case must be determined on its own individual merits. Awards may be made where, within the relevant law, the evidence including service and medical facts and the contemporary medical understanding of the condition claimed, shows a causal link between service and the claimed condition, on the basis of the relevant burden and standard of proof as referred to in paras [9] to [10] below.

9. For claims made not later than 7 years after leaving the armed forces, Article 4 of the Service Pensions Order provides that the onus is on the Secretary of State to show beyond a reasonable doubt that the claimed disablement is not attributable to, or aggravated by, service, or that death was not due to, or hastened by, any such condition. If he cannot show this an award of War Disablement Pension or War Widow's Pension, as appropriate, may be made.

10. For claims made more than 7 years after the end of service, Article 5 of the Service Pensions Order puts the onus on the claimant to raise, by way of reliable evidence, a reasonable doubt that the claimed condition is attributable to, or aggravated by, a service injury or that death was due to or substantially hastened by an attributable injury or the aggravation by service of an injury. If he does so, an award of war pension may be made.

Case Law -

11. The High Court has held that the word "reliable", in the context of Article 5, cannot have been intended to mean "convincing", but means more than "fanciful". A High Court Judge held that, with particular reference to "changes of medical opinion" that "there are... in my judgement, three stages: no reasonable doubt, reasonable doubt, and consensus". A war pensions claim under Article 5 would pass the test at the point where the (reliable) evidence raised a reasonable doubt, but: "a mere hypothesis based on a limited study.... would not have created a "reasonable doubt" within the terms of Article 5(4)."The real question, however, it held, is whether the evidence raises a reasonable doubt in the mind of the Secretary of State (SoS). If he finds the evidence unreliable it obviously will not raise a reasonable doubt in his mind. (case of Edwards 1992 HCJ no. CO/2281/90).

12. The Courts have also held that a conflict of medical opinion does not, of itself, mean that a reasonable doubt has been established, and that a claim must therefore succeed. This applies irrespective of the eminence or authority of those expressing the opinions. In the case of Tigg v The Minister of Pensions the presiding Judge stated " Merely because a doctor of eminence, and I have no doubt the doctor in this case was of very great eminence, is expressing a view contrary to the view expressed by the medical witnesses called on behalf of the

Ministry, does not mean there is a doubt and the Appellant must therefore be entitled to a pension. It is a question of fact for the Tribunal" (cases of Tigg ROSWPA vol.5 p.141 and Howard ROSWPA vol.5 p.515) .

13. In particular in assessing evidence regard has been paid to:

- whether conclusions of studies are hypotheses; or whether there is supporting evidence, which goes beyond hypothesis, and if so its basis
- the reaction of other experts in the field to the evidence
- the weight of overall evidence on the matter.

14. Evidence for any new approach in science must always be considered and weighed relative to the existing body of evidence on a subject, with account taken of the robustness and authority of new studies. In particular the design and methods, sample size, case and control selection, statistical validity, repeatability of findings, approach to bias and possible alternative factors and hidden influences. Other important factors include whether the findings have been replicated by other independent researchers and the overall plausibility/consistency relative to contemporary understanding.

Ionising radiation

15. Exposure to radiation in all its forms is part of being alive. Ionising radiation is taken to mean radiation of high enough energy to displace electrons from atoms and includes cosmic rays, gamma rays, X-rays, alpha and beta radiation. The average level of exposure to natural background radiation varies throughout the world dependent mainly on the geology of the underlying earth. In the UK it is about 2.2 mSv (millisieverts) per annum average. There is, however, a range and it is much higher in areas of igneous rock such as Scotland.

16. Tissues vary in their sensitivity to ionising radiation and different types of ionising radiation have different capacity to cause tissue damage and hence adverse health effects. As no dose of ionising radiation is considered safe, natural background is generally considered the cause of a proportion of the cancers which occur in a population. In the UK about a third of the population is affected by, and about a quarter will die of, malignant disease. However there is no clear correlation of background level and cancer incidence and areas with high total backgrounds (such as Kerala and the Andes) demonstrate no excess malignancy. By contrast the UK with one of the lower average backgrounds has one of the highest cancer incidences in the world. A synopsis on **ionising radiation dose, radiological protection and the health effects of ionising radiation is at Annex A.**

UK atmospheric nuclear tests

17. Between 1952 and 1958 the UK carried out 21 atmospheric nuclear tests (12 in Australia, 9 at Christmas Island), in the South Pacific. The radiological safety standards at the UK atmospheric nuclear trials in the 1950s were based on the

then consensus of international scientific opinion as formulated by the International Commission on Radiological Protection. A fundamental principle was to keep any exposure as low as possible. Many of the detonations involved high air bursts falling freely. The risk of significant contamination of land occupied by service or civilian participants from these air bursts was avoided by careful selection of weather conditions and environmental monitoring following the tests. The natural background radiation at Christmas Island is very much less than that of average UK locations. Overall it is considered that almost all the British servicemen involved in the UK nuclear tests received little or no additional radiation exposure as a result of participation. Further details of the tests will be found at **Annex B**.

The National Radiological Protection Board (NRPB) nuclear test follow up studies

18. As a result of concern amongst some test participants about the effects that participation could have had on health, in 1983 the Ministry of Defence commissioned an independent study by the NRPB to investigate whether the health of participants showed any correlation with radiation exposure.

19. This comprehensive cohort study compared the mortality and cancer incidence in over 20,000 test participants with that of a similar-sized control group of ex-servicemen who had not participated in the test programme.

The term 'test participant" has a particular definition and includes servicemen present at the due dates, at any of the following test sites and experimental programmes

Operation	Site	Date
Hurricane Mosaic	Monte Bello W Australia	April 1952-June 1956
Totem	Emu Field S Australia	August 1953-August 1957
Buffalo Antler Minor trials	Maralinga S Australia	April 1955-August 1967
Grapple X Y Z Brigadoon	Christmas Island S Pacific	June 1956-June 1964
Grapple	Malden Island S Pacific	October 1956-June 1964
	RAAF Pearce W Australia	May 1956-August 1956
	RAAF Edinburgh S Australia	August 1956-November 1960

There is no requirement for presence at actual detonations.

At the RAAF sites the work included cloud sampling and handling contaminated aircraft. RN ships were associated with tests at Monte Bello, Malden and

Christmas Island. The Minor Trials, did not involve nuclear detonations. They took place at Maralinga (Tims, Rats and Vixen A and B) while Kittens was at Emu field. Major clean up operations took place at Christmas Island in 1964 and Maralinga in 1964 and 1967.

20. The main conclusions of the first NRPB Report (Darby et al 1988) were that presence at the nuclear weapons test sites had increased the risk of multiple myeloma and leukaemia (other than chronic lymphatic leukaemia) compared with service controls. This was not considered to be due to ionising radiation exposure. There was a particularly low rate of the conditions in the controls and those sub groups considered most highly radiation exposed did not show the highest rates of the conditions.

21. Otherwise presence at the sites

- did not have a detectable effect on the participants' expectation of life,
- did not have a detectable effect on participants' risk of developing any other malignancy.

22. The study was extended and the second NRPB Report (Darby et al 1993) produced an additional 7 years data

- confirmed the overall conclusion of the 1988 Report; that participation in the tests had no detectable effect on the participants' expectation of life nor on their risk of developing most cancers.
- concluded that the small hazard of multiple myeloma suggested by the 1988 Report was not supported by the additional data although the possibility of some small risk of developing leukaemia (other than chronic lymphatic leukaemia) in the first 25 years after participation could not be ruled out.

With regard to other cancers the report concluded that:

- overall the number of deaths and cancer incidence amongst participants is lower than amongst the control group
- as expected because a large number of diseases were considered, any excesses in participants are due to chance.

23. Following pressure for a further investigation into the alleged effects of exposure a 3rd NRPB study was commissioned. The report of the study which extended the follow up period to 1998 was published in February 2003 (Muirhead et al 2003). Key findings were :-

- reaffirmed the overall findings of the 1988 & 1993 reports that participation in the Tests had no detectable effect on the participants expectation of life nor on their risk of developing most cancers.

- confirmed the conclusion of the 1993 report on the alleged association between participation in the UK test programme and multiple myeloma that there is no evidence to support a link.

- suggested particularly in 2 – 25 years after first test participation a small increase in risk of leukaemia (excluding chronic lymphatic leukaemia) among test participants relative to controls although the difference in rates between the 2 groups is narrowing with longer follow up.

24. Applying the test set out at para 13 and 14 of this statement, the Secretary of State considers the National Radiological Protection Board Reports, of which a principal author is Sir Richard Doll, to be reliable evidence.

In particular the following points are noted:-

- The study identified the test participants, and followed them up to monitor the occurrence of disease and death in the participant population. It then compared this, over the same time period with the rates in both a service and civilian control population.

- The study involved 20,000 subjects and an equal number of controls

- The reports describe in detail the efforts made to ensure sample completeness and to control bias.

- The study limitations are discussed by the authors and conclusions are reasoned and restrained.

The Secretary of State's opinion as to the reliability of the evidence in the reports is in accord with the general opinion of the scientific community. Positive reactions include comment from Prof John Kaldor of New South Wales (Kaldor 1999) and the US Presidential Advisory Committee on Human Radiation Experiments (Thomas 1998).

Impact of the NRPB reports on the Secretary of State's normal policy

25. Based on the first report, Secretary of State's normal policy became to award war pension for claims for leukaemia (other than chronic lymphatic leukaemia) and multiple myeloma in those present at test sites. The policy also included awards for primary polycythaemia rubra vera, the red blood cell equivalent of leukaemia. In light of the 1993 report, Secretary of State's normal policy was revised. Since then, on the basis of presence at atmospheric nuclear test sites new claims for multiple myeloma are rejected but awards continue to be made for leukaemia (other than chronic lymphatic leukaemia) and primary polycythaemia rubra vera having clinical onset within 25 years of first presence at the test sites. On the basis of the findings of the 2003 report the Secretary of State's current normal policy remains unchanged .

26. The reports did not causally link development of those conditions to ionising

radiation exposure and the policy is not an acknowledgement that those present at the tests were exposed to harmful levels of ionising radiation. The accepted service link is purely presence at the test sites.

27. Having carefully considered the reports the Secretary of State is of the opinion that they do not provide reliable evidence to raise a reasonable doubt that other cancers (eg liver and bladder) might be attributable to service in the armed forces because of presence at the nuclear test sites. Consequently it is his normal policy that awards may not be made for solid cancers on the basis of presence at atmospheric nuclear test detonations or clean-up operations alone. However it is also his normal policy that an award of war pension may be made for cancer in any case where there is reliable evidence of service exposure to sufficient level of ionising radiation and there is a recognised causal link between the claimed condition and such accepted exposure.

Children of test participants

28. The sample on which the 1988, 1993 and 2003 NRPB Reports was based did not include the children of test participants and was solely concerned with a study of the test participants themselves and not with any possible affect their participation might have had on their progeny.

29 Any claim for compensation for a child in respect of disablement or death said to be due to the parent's participation in the UK Tests would not fall within the scope of the SPO.

Position of civilian test participants eg MOD civilian employees

30. Compensation for civilians or their widows employed by the MOD who participated in the tests and who claim that disablement or death is due to participation is similarly not covered by war pensions legislation. In addition to civil action against MOD there is a possibility of a successful claim to Industrial Injuries Benefit under the Industrial Injuries Scheme administered by the DWP. MoD civilian employees are also covered by the Compensation Scheme for Radiation Linked Disease.

Cases falling outside the general policy guidelines

31. Any reference to the Secretary of State's "normal policy" indicates that the policy should not be a rigid one. The merits of each individual case should be considered and discretion should be used when deciding whether to make a payment.

Evidence of cancer causation by ionising radiation

32. Evidence that ionising radiation can cause human cancer has come from several sources. These include follow-up of patients therapeutically irradiated for malignant conditions, such as cancer of the cervix, and non-malignant conditions like ankylosing spondylitis, follow-up studies on UK, US, Australian and New Zealand service personnel present at atmospheric nuclear test sites, and most notably from the Japanese atomic bomb survivor studies.

33. The Japanese atomic bomb survivor data shows evidence of an increase in cancer incidence but only in individuals exposed to levels of ionising radiation of 50 mSv and above. (The UK natural background radiation is 2.2 milliSieverts per annum

average.) There is no firm evidence from any human low dose epidemiological studies which unequivocally demonstrates an increase in cancer incidence.

34. Since everyone is exposed to ionising radiation and not everyone develops cancer other factors must be relevant. Cancers induced by ionising radiation are indistinguishable from those due to other more common causes such as diet, tobacco, alcohol etc. In addition to the dose of radiation delivered, the type of radiation, its duration of exposure ie an acute high dose or a chronic low dose, the particular tissue irradiated and the age of the individual at the time of the radiation are all known to be important. Taking the overall evidence on these matters into account and in the absence of a positive threshold dose of ionising radiation, the convention is to accept that no dose of ionising radiation is completely free from risk of cancer and that the risk increases linearly with dose.

35. There is, however, a spectrum of risk dependent on the factors discussed above and a standard international approach to estimation of the probability that a particular cancer in a particular patient is causally linked to ionising radiation has been established. (IAEA - Tech - Doc 870 (1996)). The probability of causation approach requires dosimetry information on the individual's exposure. The Secretary of State's normal policy in war pensions is that there is reliable evidence to raise a reasonable doubt that there is a causal link between ionising radiation exposure and the following cancers:-

leukaemia (other than chronic lymphatic leukaemia)
multiple myeloma
non-Hodgkin's lymphomas
polycythaemia rubra vera
female breast
lung
oesophagus
stomach
colon
primary cancer of the liver
gall bladder
thyroid
urinary bladder
non-melanoma skin
brain
salivary gland
bone
ovary
uterus and vagina
testis
kidney
pancreas (Pierce (1996): Thompson (1994)

In war pension claims for disablement or death due to these conditions **and** where the Secretary of State has accepted **service related ionising radiation exposure,** a war pension award will be considered. The Secretary of State does not accept evidence of participation in nuclear tests as itself equating to proof of service related ionising radiation exposure.

Evidence of radiation induction of non-cancer conditions

36. Reports of the atomic bomb survivor follow-up studies, suggests that ionising radiation exposure may also be associated with non-cancer diseases. (Kodama (1996): Schull et al (1998)). Associations have been described with uterine fibroids and certain non cancerous thyroid and para-thyroid tumours. The issue of a possible link between ionising radiation exposure and cardiovascular disease has also been raised in relation to war pensions. A review of the current evidence is at Annex C.

37. On present evidence the Department does not accept that a reasonable doubt is raised by reliable evidence that ionising radiation exposure is causally related to atherosclerosis or any of its manifestations.

References

Darby et al (1988) Report on Mortality and Cancer Incidence in UK Participants in UK Atmospheric Nuclear Weapon Tests and Experimental Programmes NRPB-R214

Darby et al (1993) Report on Mortality and Cancer Incidence 1952-1990 in UK Participants in the UK Atmospheric Nuclear Weapon Tests and Experimental Programmes NRPB-R266

Kaldor (1999) Report to the Minister assisting the Minister for Defence on recent studies of nuclear test veterans. University of New South Wales, Australia.

Thomas (1998) Letter to the Editor J Radiol Prot; Vol 18; No 3: 209-210

Pierce (1996) Studies of the mortality of atomic bomb survivors. Report 12, Part 1. Cancer: 1950-1990. Rad. Res. 146, 1-27.

Thompson (1994) Cancer incidence in atomic bomb survivors Part II: Solid tumours, 1958-1987. 1994. Rad. Res. 137: S17-67.

IAEA – Tech – Doc 870 (1996) Methods for estimating the probability of cancer from occupational radiation exposure.

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Radiation dose

1. The first definition of a unit of radiation dose was made in 1928 by the International Congress of Radiology. The rontgen (R) was defined as that quantity of radiation which produces in 1cm of air one unit of charge of either sign, thus defining a unit of exposure. Units of **absorbed dose**, the actual energy absorbed in the tissue being irradiated are now used. The radiation absorbed dose or **rad** is now cited in SI (System Internationale) units - joules per kg - of absorbing material. The fundamental unit - 1 joule/kg is 1 gray (1Gy) equivalent to 100 rads (R).

2. Different radiation types have greater or lesser effect per unit dose so they are all expressed relative to the effects of X-rays ie a unit equivalent dose is used. To calculate the rontgen equivalent in man (**rem**) - the absorbed radiation dose is multiplied by a radiation weighting factor - dependent on type and energy of the radiation. The current SI unit of equivalent dose is the **sievert**. For X-rays and gamma rays the equivalent dose in sieverts and the absorbed radiation dose in grays are the same. The relationship between the different dose units is:-

   1 gray (Gy) = 1 joule/kg = 100 rads (R) = 100 rems (r) = 1 sievert (Sv) = 1,000 millisieverts (mSv) = 1,000,000 microsieverts (microSv)). Typical doses of radiation include:-

   Chest X-ray - 0.02 mSv
   Brain scan - 7 mSv
   Bone scan - 4 mSv
   Average annual UK dose from cosmic rays - 0.26 mSv
   Average annual UK dose from gamma rays - 0.35 mSv
   Average annual UK dose natural background radiation – 2.2 mSv

Radiological protection

3. Since the days of Marie Curie it has been appreciated that ionising radiation exposure may be hazardous to health. Radiation dose limits were first recommended for ionising radiation exposure in 1928. The statutory limit on the amount of radiation to which the general public may be exposed in excess of natural background radiation and excluding medical exposure is set, from 1 January 2000 at 1 mSv per annum.

4. The most important source of man made exposure is medical investigation which accounts for 90 per cent of man made exposure. Average natural background radiation is raised to 2.6 mSv by all man made exposure. UK estimated experience excluding medical investigation is 0.04 mSv. Other statutory limits include occupational dose limits. From
   1 January 2000 these are 20 mSv per annum for classified workers and 6 mSv per annum for unclassified workers.

Health effects of ionising radiation

5. Adverse health effects of ionising radiation are independent of the source of radiation and are of 2 types. Early and late.

Early effects (also called deterministic)

- These effects usually arise shortly after exposure, usually within hours or weeks.
- There is a threshold dose, beneath which no effects are seen.
- This threshold is relatively high, exceeding natural background radiation levels at all parts of the planet by several hundred fold.
- The severity of the effect varies directly with dose.
- Duration of exposure is also important and for a given total dose, acute exposure is more harmful than a protracted dose.
- The tissues affected are those whose cells have a high turnover rate ie bone marrow - skin - gastro-intestinal tract.

Late effects - also called stochastic/probablistic

- These effects arise years (2-40 or more) after exposure and the probability depends on the level of the dose.
- There appears to be no threshold and the severity of the effects is not dose dependent.
- This means that there is a finite risk even from low level natural background radiation. At the same time persons exposed to high dose may suffer no ill effects.
- The 2 main late effects are induction of cancer and hereditary disease in subsequent generations.
- All diseases which can be radiation induced can also occur naturally or in relation to other exposures - cigarette smoke, alcohol, diet (both excesses and deficiencies), occupational exposures - and are not distinguishable on the basis of cause.
- Current best evidence is that radiation of all types gives rise to less than 2% of all cancers worldwide. The most important carcinogenic type of radiation is in fact ultra-violet light (UVB) not ionising radiation.
- Not all types of cancer have been shown by evidence to be caused by ionising radiation.
- Hereditary effects have not been demonstrated in humans but there is such evidence in some types of animals.

<u>Effects of total body irradiation</u>

Equivalent dose (Sv)	**Effect**
Sublethal to man	
0.0001 (0.1 mSv)	Around 2 weeks' natural background radiation, no detectable effect
0.001 (1 mSv)	Around 6 months' natural background radiation, no detectable effect
0.01 (10 mSv)	No detectable effect

0.1 (100 mSv)	Minimal decrease in peripheral lymphocyte count, no clinical effect
1 (1000 mSv)	Mild acute radiation sickness in some individuals (nausea, possible vomiting), no acute deaths, early decrease in peripheral lymphocyte count, decrease in all WBC and platelets at 2-3 weeks, increase in late risk of leukaemia, solid tumours

Equivalent dose (Sv)	**Effect**
Lethal to man	
10 (10,000 mSv)	Severe acute radiation sickness, severe vomiting, diarrhoea, death within 30 days of all exposed individuals. Severe depression of blood cell and platelet production, damage to gastrointestinal mucosa
100 (100,000 mSv)	Immediate severe vomiting, disorientation, coma, death within hours
1000 (1,000,000 mSv)	Death of some micro-organisms, some insects within hours
10,000 (10,000,000 mSv)	Death of most bacteria, some viruses
100,000 (100,000,000 mSv)	Death of all living organisms, denaturation of proteins

Annex B

UK atmospheric nuclear tests

1. From information available the Ministry of Defence estimated that only about 10% of all participants were likely to have been exposed to measurable levels of ionising radiation. The relevant groups of personnel were in order of likelihood of exposure:-

    - RAF aircrews involved in sampling from airburst clouds (205 men). Mosaic. Totem. Buffalo. Antler. Grapple.

    - RAF decontamination flight crews who sluiced the aircraft (129 men).

    - RN personnel on HMS Diana when she sailed through the fallout at Operation Mosaic. (282 men)

    - The officers of the Buffalo Indoctrinee Force and Target response group. They assembled to observe at first hand the effects of the detonation (249 men).

    - Others – with recorded exposures greater than zero (1123 men).
      The total of the five groups equals almost 2,000 men.

2. A nuclear explosion can produce effects on health via visible light, heat, air blast and ionising radiation.

3. The visible light from a nuclear detonation can cause flash-blindness at considerable distances and permanent eye injury at short ranges. (There is no absolutely safe range for this effect). Protection at UK trials was assured by mustering all persons and ordering them to face away from the detonation with eyes covered.

4. The heat from a nuclear detonation can cause first-degree burns to bare human skin at ranges up to three kilometres from a ten-kiloton detonation or twenty-one kilometres from a one-megaton detonation. Protection is by maintaining a sufficient distance.

5. Air blast is unlikely to cause injury to a person more than three kilometres from a ten-kiloton burst or six kilometres from a one-megaton burst. Protection is again by maintaining a sufficient distance.

6. The ionising radiation exposure associated with nuclear detonations is of two types. Firstly, a large pulse of radiation is emitted by the device as it explodes. This is absorbed by the air over distances of a few kilometres. To be close enough to receive a significant dose of ionising radiation an individual would also be within the lethal range of the air-blast and heat. Secondly, ionising radiation, under certain circumstances, is also emitted by the radioactive particulate fallout. The fallout particulates are carried downwind after the detonation. Wherever possible, UK trial detonations were carried out as high airbursts to minimise fallout. All UK atmospheric nuclear trials devices produced yields at, or very close to, the design figure.

7. Specialist instrumentation was used at the trials to measure ionising radiation.

Personal dosemeters, designed to estimate the dose to an individual from photons and beta particles, were carried typically for a month. The film badge consists of a piece of photographic film, sealed in a light-tight package bearing a unique number, and contained in a cassette adapted for securing to the clothing. Exposure to ionising radiation causes blackening of the film. After conventional photographic developing, the film is compared with a standard and an estimate of dose obtained. It is sensitive to photons (gamma rays and X-rays) beta particles and low-energy neutrons, and can distinguish between them.

8. The Atomic Weapons Establishment, Aldermaston holds the film badge records of the test participants. Badges were not issued to all personnel – Ministry of Defence estimate that 21% of total participants had badges. In general more badges were issued for the earlier tests (96% of those present at Operation Hurricane had a badge while only 20% of those at Operation Grapple). The reducing percentage of people monitored was informed by the actual exposure levels and characteristics of preceding operations. In general those men most likely by the nature and location of their duties to be exposed to measurable doses were monitored. Not all of those monitored showed a recordable dose. Less than 500 individuals received 5mSv or more and about 80 of these received 50 mSv. Doses recorded refer to the entire test programme for the individual and in some cases this will be several years. Of the 80, the majority were RAF crew who took part in cloud sampling.

9. Dose from ionising radiation can also arise by internal contamination, through breathing or swallowing contaminated dust. Although alpha-emitting materials would be the most hazardous in this respect, they are a very small component of fallout compared to beta and photon-emitting materials. The risk of internal dose was minimised at the trials by ensuring that only essential and fully protected personnel were ever in areas where internal contamination was possible. In addition, while a film badge did not measure internal dose directly, to receive a significant internal dose, an individual would have to enter an area where there were high levels of resuspendable fallout emitting photon and beta radiation. It is highly unlikely that this could happen without at the same time there being a measurable external dose received as indicated by his film badge.

10. The Ministry of Defence records identified those men present at the minor Maralinga trials who were at highest risk of radionuclide ingestion or inhalation. There were 847 in total. In the NRPB study, this group was considered separately. It did not show any increased risk of multiple myeloma, leukaemia or other malignancies relative to the rest of the participant group.

11. In conclusion, almost all the British servicemen involved in the UK nuclear tests received little or no additional radiation as a result of participation. If personnel who served at Christmas Island at that time had been stationed in the UK in an average location their dose of naturally occurring ionising radiation would have been 3 times greater than it was at Christmas Island.

Ionising radiation and heart disease

1. Until the 1960s the heart and blood vessels were thought to be completely resistant to ionising radiation (Warren 1942). Since then reports have appeared describing inflamation of the heart lining, and conduction disorders from damage to the electrical system following high dose mediastinal irradiation of malignant tumours. Today these affects of high dose ionising radiation exposure are generally accepted. (Stewart et al 1984).

2. The situation regarding a link between ionising radiation - particularly low dose ionising radiation - and atherosclerotic disease is less clear. An association between ionising radiation and atherosclerosis has not been established. (Corn et al 1990).

3. In animal studies, coronary sclerosis has been found in rabbits, rats and pigeons which have been irradiated **and** which have high serum cholesterol. The evidence is that both elements are required (Gold 1961).

4. In 1958 a human case study reported a myocardial infarction following deep X-ray therapy and since then there have been further reports linking death due to coronary disease following radiotherapy for medical conditions including Hodgkin's disease, breast cancer, seminoma. (Prentice 1965: Stewart et al 1967: Tracy et al 1974: McReynolds et al 1976). In these studies confounders were present eg they did not control serum cholesterol, blood pressure or cigarette smoking. In addition the study subjects were already ill. The reports do not prove a causal relation between ionising radiation and ischaemic heart disease.

5. Further information from long term follow-up studies of heavily irradiated populations (Host and Loeb 1986) has shown excess mortality from myocardial infarction in these populations. There are also case reports of cerebral infarction following radiotherapy to head and neck and of peripheral vascular disease of the lower limbs following pelvic irradiation. However, these effects have only been reported where the irradiation procedure delivered a very large dose of ionising radiation (20,000-60,000 mSv) and the results cannot be extrapolated to populations exposed to low doses of irradiation. Studies involving up to 20 years follow-up of patients irradiated according to more recent radiotherapy procedures ie using much lower doses have shown no significant difference in myocardial infarction death rate between irradiated and control populations. (Hancock et al 1988). A detailed discussion of these studies was presented in a review paper by Kodama (1995).

6. An American 50 year follow-up study of 30,000 radiologists suggested that in those who started practice between 1920 and 1929 there were an excess of coronary deaths compared with other medical specialists. However, a British 60 year follow-up study of 25,000 radiologists did not confirm this effect and similarly follow-up studies of 14,500 patients treated with deep X-ray therapy for ankylosing spondylitis over 30-50 years suggested no increase in coronary deaths. Results are therefore

inconsistent.

7. Most follow-up studies have focussed on mortality rates, which is subject to many uncertainties and inaccuracies. A more accurate estimate of the association would come from incidence studies in large populations with lengthy follow-up and controlled risk factors.

8. The issue of association between ionising radiation and stroke or coronary heart disease in non-medical settings has been addressed periodically in the atomic bomb studies. In particular in the Radiation Exposure Research Foundation Life Span Study (RERF LSS) Technical reports. Until the report, LSS6, summarising the results for period 1950-70 there was no suggestion of a relation between atomic bomb radiation exposure and mortality from stroke or coronary disease. That analysis reported an increased mortality from coronary disease in women exposed to 100 mSv or more. The increase was particularly marked where dose exceeded 500 mSv. The trend was not however confirmed in the subsequent report, LSS9 for the period 1950 - 1978, although this did show increased mortality from "all diseases other than cancer" where exposure exceeded 2000 mSv.

9. The report on the period 1950-85 (Shimuzu et al 1992) used a new method of exposure dose estimate and showed clearly increased mortality from circulatory disease - including stroke and cardiac disease again in heavily exposed survivors.

10. The issue of accuracy of death certificates for the RERF studies has been examined (Carter et al 1991) and it is apparent that death certification for cardiovascular disease is less accurate than for malignancies. In addition it is the case in these mortality studies that other known cardiac risk factors cannot be controlled.

11. Only a few studies have yet been published which look at the **incidence** of coronary heart disease and stroke in relation to ionising radiation exposure associated with the atomic bombs. For the period 1958-1964, Johnson et al (1966) found no association. A later report covering the period 1958 - 1974 suggested an increase of stroke and coronary disease in females heavily exposed (over 2000 mSv) in Hiroshima. The effect was not seen in men or in Nagasaki survivors.

12. Kodama's 1994 study, now covering the period up to 1990, again confirmed an increase in myocardial infarction incidence in heavily exposed survivors regardless of age, gender or location, although the excess of myocardial infarction was very small compared with cancers. (The relative risk of myocardial infarction at 1,000 mSv exposure was 1.17. The associated p value is 0.02 with a confidence interval (95%) of 1.01 - 1.36). Lifestyle risk factors for coronary disease were not adjusted for. At this date, therefore, further studies are needed to determine the matter.

13. The Department's position in the context of exposure to low dose ionising radiation exposure is that present overall evidence does not raise a reasonable doubt that such exposure is causally associated with atherosclerosis or any of its manifestations.

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Glossary

Absorbed dose See **dose.**

Acute radiation syndrome (ARS) The onset, within hours of high **dose** whole body **irradiation,** of nausea and vomiting followed by destruction and diminished (or absent) replacement of essential blood cells resulting in vulnerability to serious infection and bleeding; recovery is possible but with increasing **doses** these effects are more severe and death more likely.

Alpha particle A particle consisting of two protons plus two neutrons. Emitted by a radionuclide.

Background radiation **Ionising radiation** from naturally occurring **radionuclides** both in the environment (from soil, rock and building materials and from space – cosmic radiation) and in the body.

Beta particle An electron emitted by the nucleus of a radionuclide. The electric charge may be positive, in which case the beta particle is called a positron.

Contamination The suspension in air or deposition of **radionuclides** upon, or in, the ground, water and other surfaces, and personnel and equipment.

- **External contamination.** Of a person - deposition, general or localised, of **radionuclides** upon all or any of clothing, hair, skin and, or equipment.
- **Internal contamination** Of a person - deposition within the body, usually by inspiration, by ingestion or sometimes through penetration of (usually broken) skin by **radionuclides** which will then **irradiate,** the cells of surrounding body tissues.

Cosmic rays High energy ionising radiations from outer space.

Decay The process of spontaneous transformation of a radionuclide. The decrease in the activity of a radioactive substance.

Dose The amount of **ionising radiation** received as deduced from the energy absorbed from an external radiation source.

- **Absorbed dose** Quantity of energy imparted by ionising radiation to unit mass of matter such as tissue. Unit gray, symbol Gy. 1Gy = 1 joule per kilogram
- **Equivalent dose** The quantity obtained by multiplying the absorbed dose by a factor to allow for the different effectiveness of the various ionising radiations in causing harm to tissue. Unit sievert, symbol Sv.
- **Effective dose** The quantity obtained by multiplying the equivalent dose to various tissues and organs by a weighting factor appropriate to each and summing the products. Unit sievert, symbol Sv.

Dosemeter A small device worn on the person to measure absorbed energy and from which a record of **Absorbed Dose** may be obtained.

Dosimetry The estimating, recording and maintaining of records of **dose.**

Emitter A **radionuclide** decays by emission of certain radioactive particles and, or electromagnetic radiation. A particular **radionuclide** may be described as an **alpha** or **beta** or **beta/gamma** emitter.

Fallout The transfer of radionuclides produced by nuclear weapons from the atmosphere to earth; the material transferred.

Fission products The two, invariably radioactive, fragments remaining after an atom has been split (undergone fission).

Gamma ray A discrete quantity of electromagnetic energy without mass or charge. Emitted by a radionuclide. Cf X-ray.

Ionising radiation Radiation that produces ionisation in matter. Examples are alpha particles, gamma rays, X-rays and neutrons. When these radiations pass through the tissues of the body, they have sufficient energy to damage DNA.

Ionisation The process by which a neutral atom or molecule acquires or loses an electric charge. The production of ions.

Monitoring The process of searching for the presence of and then measuring, reporting and recording radiation **dose rates** found within a given area or on a person.

Neutron A nuclear particle (similar to a hydrogen atom but without electrical change); emitted during fission and fusion by only a few **radionuclides;** long range (kilometres) in air and highly penetrating; an external **hazard** only at detonation; densely **ionising.**

Non-ionising radiation Radiation that does not produce ionisation in matter. Examples are ultraviolet radiation, light, infrared radiation and radiofrequency radiation. When these radiations pass through the tissues of the body they do not have sufficient energy to damage DNA directly.

Radiation weighting factor (RWF). A factor intended to take account of the relative biological effectiveness of different types of radiation according to both their energies and how densely ionising they are.

Radionuclide An unstable nuclide that emits ionising radiation.

X-ray A discrete quantity of electromagnetic energy without mass or charge. Emitted by an X-ray machine. Cf gamma ray.