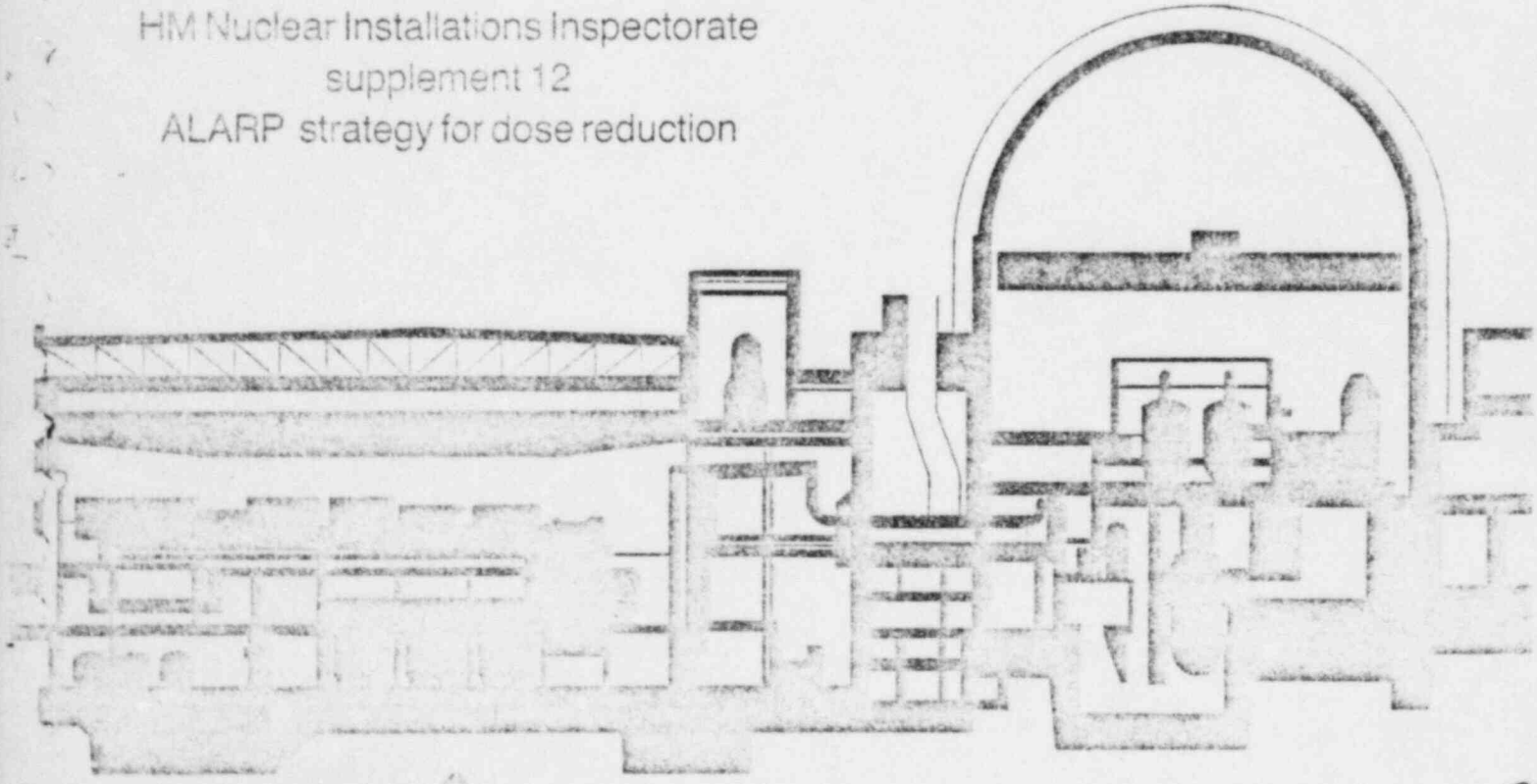
NII 01 (Supp 12)

Sizewell B

a review by
HM Nuclear Installations Inspectorate
supplement 12
ALARP strategy for dose reduction



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A review by HM Nuclear Installations Inspectorate
Supplement 12: ALARP strategy for dose reduction
NII 01 (SUPP 12)

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INTRODUCTION

1 In paragraph 14.17 of its Review of the CEGB's Pre-Construction Safety Report (PCSR) for Sizewell B (ref 1), the Inspectorate concluded that the PCSR did not give a sufficient description of the design strategy for keeping all exposures to ionising radiations as low as is reasonably practicable (ALARP). It was noted in paragraph 14.18 that the CEGB had agreed to furnish the Inspectorate with a further report explaining its ALARP strategy and justifying its claim that it had done all that was reasonably practicable to reduce the production of crud (activated corrosion products) and remove it from the primary circuit. The CEGB had been asked to demonstrate that it had made reasonable attempts to quantify its ALARP judgements by the use of cost-benefit analysis on the lines recommended by the International Commission on Radiological Protection (ICRP) in its Publication 26 (ref 2).

2 This report presents the Inspectorate's views on the CEGB's strategy for dose reduction on Sizewell B, as presented in PWR R646* (ref 3). Since one section of the report deals with radioactive waste management systems and the balance between the exposure of on-site workers and of the general public from radioactive waste management procedures, the Inspectorate's assessment of this section has been carried out in consultation with the Department of the Environment (DOE) and the Ministry of Agriculture, Fisheries and Food (MAFF).

SAFETY ASSESSMENT OBJECTIVES

3 In Section 14 of the Review the Inspectorate commented on the extent to which the design had been optimised to satisfy its three fundamental Safety Assessment Principles (see section 1 of ref 4)

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* R646 and many of the PCSR supporting reports are NNC documents. However, these documents are endorsed by the CEGB and constitute part of its safety case. In this report by the Inspectorate, therefore, statements made in R646 are attributed directly to the CEGB. Similarly, statements made by the NNC at formal meetings, eg in relation to its future work programme, are also given the same attribution.

related to the radiological protection of persons on and off the site during normal operation, namely principles 1, 2 and 3:

> "(1) No person shall receive doses in excess of the appropriate dose equivalent limit as a result of normal operation,
>
> (2) The exposure of persons shall be kept as low as is reasonably practicable (ALARP),
>
> (3) Having regard to principle (2), the collective dose equivalent to operators and to the general public as a result of operation of the nuclear installation shall be kept as low as is reasonably practicable (ALARP)".

4 To ensure that the proposed station will meet the first of these three principles, the following assessment level for normal operation is specified in principle 6:

> "The dose equivalent or dose equivalent commitment from routine or planned operations received by any occupationally exposed person on site should be no more than one third of any of the appropriate annual dose equivalent limits".

Similarly, in the CEGB's design safety guidelines (ref 5), the design dose target for occupationally exposed workers in the power station is given in section 2.1(i) of Annex XV as:

> "The maximum individual effective dose equivalent to any member of occupationally exposed staff shall not exceed 1.0 rem (10 m Sv) per annum."

The CEGB has stated (ref 6) that the target figure of 1 rem was chosen in the belief that it represented the lower limit of what was reasonably achievable. The Inspectorate does not share this view but, nevertheless, believes that this target is useful in that it helps to ensure that the annual dose equivalent limit of 5 rems is unlikely to be exceeded. Furthermore, the Inspectorate accepts that the CEGB's

design dose target of 1 rem is lower than its assessment level in principle 6 (which is one third of 5 rem ie approximately 1.7 rem effective dose equivalent) and that it should, with the appropriate attention being given to reducing doses so far as is reasonably practicable, provide an acceptable basis for radiological protection control.

5 In addition to the individual dose target discussed above, the CEGB also specifies a design target for the station collective dose to occupationally exposed workers in terms of man-rem per MW(e) installed capacity per year. The target chosen by the CEGB is 0.2 man-rem per year per MW(e) installed capacity, which is equivalent to a collective effective dose equivalent for Sizewell B of 240 man-rem per year. The Inspectorate accepted, in paragraph 14.11 of the Review, that this arbitrary design target, if achieved, would rank Sizewell B with the top 10% of operating PWRs in the USA.

6 However, the Inspectorate does not accept a predetermined design dose target, whether collective or individual, as a suitable basis for demonstrating that the ALARP requirement has been achieved since decisions about what is reasonably practicable should, inter alia, take account of the predicted exposures of individuals or groups of individuals when carrying out the range of duties involved. For this reason the Inspectorate's principle 180 specifies that:

> "To ensure that all doses are kept as low as reasonably practicable the safety submission should specify a scheme for the limitation of dose equivalent rates to persons working on site and site visitors from normal operation, routine maintenance and inspection .....".

7 The scheme (or strategy) should cover all sources of radiation arising from the plant and should incorporate all reasonably practicable measures for reducing doses. It is required prior to licensing a nuclear power plant in order that the Inspectorate may be satisfied that the more important aspects of plant layout and choice of design options have been taken into account at an early stage.

8 Exposure records from PWRs already operating, particularly those in the USA for which the radiation dose data is extensive, have been available for some time. In general, the average collective dose to operators continues to rise each year. In 1980 it was 500 man-rem for the average PWR in the US, nearly 70% of which was incurred through in-service inspection and maintenance operations (ref 7). By 1981 the average collective dose had risen to about 600 man-rem per year (ref 8). The high doses experienced during maintenance and inspection operations on PWRs are dominated by the presence of activated corrosion products, principally cobalt 58 and cobalt 60 deposited on the inner surfaces of primary circuit pipework and components, which build up over the life of the plant.

9 In Table 12.4-49 of the PCSR the annual collective dose for the Sizewell plant is predicted to be 231 man-rem, with the following contributions from the different items of work: in-service inspection and maintenance, 48%; refuelling, 7%; waste processing, 10%; operation and surveillance, 15%. Since the doses received during maintenance and inspection procedures dominate the annual collective dose, the Inspectorate has laid special emphasis on the need to ensure that such doses are as low as reasonably practicable. In addition, however, the Inspectorate has asked the CEGB to demonstrate that all reasonably practicable steps have been taken, at the design stage, to reduce doses from the other work items contributing to the station collective effective dose. These are discussed in Chapter 12 of the PCSR and the more important contributors are subjected to cost-benefit analysis in sections 8, 9 and 10 of R646.

THE PCSR CASE THAT DOSES ARE ALARP

10 Sections 14.11 to 14.13 of the Review of the PCSR summarise the Inspectorate's assessment of the CEGB's claim that the predicted doses for Sizewell B are as low as reasonably practicable. The claim was based largely on the results of a review by the CEGB of relevant PWR experience. While the Inspectorate accepted that this had given the CEGB a good insight into the problem of reducing doses from a PWR, it

considered that this approach was too qualitative to be of use in demonstrating that the doses would be as low as reasonably practicable.

11 In discussions with the CEGB it was pointed out that the ALARP case for Sizewell B needed to be set down in a more quantified manner which demonstrated that proper consideration had been given to the following six options:

(a) choice of primary circuit materials to minimise the formation of activated corrosion products, particularly cobalt 58 and cobalt 60;

(b) choice of operating conditions to minimise the formation and transport of crud;

(c) incorporation of all reasonably practicable techniques to remove crud from the primary circuit before it can deposit in out-of-core areas, especially those areas to which access is necessary for maintenance and inspection;

(d) establishment of reasonably practicable techniques for removing deposited crud ie, decontamination;

(e) design of shielding and plant layout so as to minimise the need for persons to enter high dose rate areas;

(f) provision of remotely-operated devices to assist with operations, such as fuelling, in-service inspection and maintenance, which would otherwise involve personnel working in high dose rate areas.

12 These options are, in the Inspectorate's judgement, the main ones that should be considered in the ALARP strategy as they could lead to significant reductions in the high doses received during maintenance and similar operations.

GENERAL APPROACH ADOPTED IN R646

13 The report R646, submitted by the CEGB in response to the Inspectorate's request for an ALARP strategy, is entitled "The application of the ALARA principle to Sizewell B". The ALARA principle, that all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account, is part of the system of dose limitation recommended by the ICRP and in order to aid judgments as to what is reasonably achievable the ICRP has recommended the use of cost-benefit analysis (ref 2). The CEGB, in R646, has applied this recommendation in consideration of the six options listed in paragraph 11. However, the Inspectorate refers throughout its safety assessment principles to the ALARP principle. The phrase "reasonably practicable" is widely used in UK safety legislation and its meaning has been considered by the Courts. It implies that: "a computation must be made in which the quantum of risk is placed in one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and, if it be shown that there is a gross disproportion between them - the risk being insignificant in relation to the sacrifice - the defendants discharge the onus on them" (ref 9). The CEGB states in the PCSR (page 1.A1/2) (ref 10), and this is repeated in the Inquiry Glossary of Terms (ref 11), that ALARA has the same meaning as ALARP. The Inspectorate accepts that in practice this may often be the case since it is usual to err on the side of safety when "achieving a proper balance" in the absence of firm data. Furthermore, as the NRPB points out in reference 12, the balance in terms of cost of protection per unit dose equivalent is the minimum requirement for ALARA since there may be components of the total detriment other than health and related costs which need to be taken into account. However, to avoid any confusion about the assessment standards that it has applied to Sizewell B, the Inspectorate has reviewed R646 in terms of its ALARP principle with the interpretation of "reasonably practicable" given above.

14 In the introduction to R646 it is stated that a fundamental principle of the Sizewell B design is that it is based on an existing

well engineered design, namely that provided for the SNUPPS project. Thus, the design process has been to assess this design in detail and only introduce modifications where they have been judged to be necessary in order to meet the requirements of the CEGB's Design Safety Guidelines and the Inspectorate's Safety Assessment Principles.

15 In section 2 of R646 it is stated that an Occupational Radiation Exposure (ORE) estimate of 365 man-rem/year is given for the SNUPPS plant in Chapter 12 of the Final Safety Analysis Report (FSAR) (ref 13), and that this was confirmed by an independent NNC evaluation performed in a similar manner to that described in Section 12.4 of the PCSR. Additionally, in the SNUPPS FSAR the average individual doses associated with routine operation, routine maintenance and radioactive waste processing are shown to be 1, 3.7 and 3 rem/year respectively. Thus, in order to achieve the design objectives of the CEGB's Design Safety Guidelines, it was necessary in the CEGB's view to:

"(a) modify the SNUPPS design to reduce the total dose by a factor of 1.5, and

(b) identify those individual members of staff who with the SNUPPS design are at risk of exceeding 1 rem/year in the absence of artificial dose sharing and modify the design so that the individual dose target is achievable."

16 The first of these is seen to be necessary in order to reduce the total collective dose for Sizewell B to the CEGB's target of 240 man-rem/year. The second is understandable in view of the fact that, on average, about 65% of the annual collective dose to operators on US PWRs arises from individual doses exceeding 1 rem/year. However, whilst the achievement of such objectives is clearly worthwhile from the safety point of view it does not satisfy the ALARP requirement, as was explained in paragraph 6 above. Consequently, in sections 4 to 9 of R646, the CEGB presents the results of a cost-benefit analysis in relation to each of the options listed in paragraph 11 above. The Inspectorate's review of this analysis is described below.

ECONOMIC FACTORS

17 In paragraph 14.18 of the Review, the CEGB was asked to demonstrate that it had made reasonable attempts to quantify its judgements that the ALARP requirement had been met by the use of cost-benefit analysis on the lines recommended by the ICRP. The National Radiological Protection Board (NRPB) has given advice on the optimisation of radiation protection of persons and in section 3 of R646 the CEGB explains that the NRPB's preliminary recommendations for the monetary value of unit collective dose for occupational exposure (ref 12) and the published monetary values for exposure of the public (ref 14) were used in the cost-benefit analysis.

18 The NRPB's published advice for exposure to the public recommends three different costs of unit collective dose for the following three dose bands: < 5 mrem/year; 5-50 mrem/year; 50-500 mrem/year.

Table 1*: Cost and present worth of unit collective dose to the public

Individual annual dose equivalent band (mrem)	Cost of unit collective dose equivalent made up of dose equivalents within the band (£/man-rem)	Present worth of 1 man-rem/y for a 40 year reactor life at a discount rate of 0% (£/man-rem/year)	Present worth 1 man-rem/y for a 40 year reactor life at a discount rate of 3% (£/man-rem/year)
< 5	20	800	462
5-50	100	4,000	2,310
50-500	500	20,000	11,552

19 Similarly, in its discussion document on the monetary value of occupational exposure, the NRPB recommends three different costs of unit collective dose for the following three dose bands: 0-0.5 rem/year; 0.5-1.5 rem/year; 1.5-5 rem/year.

Table 2*: Cost and present worth of unit collective dose (occupational)

Individual annual dose equivalent band (rem)	Cost of unit collective dose equivalent within band (£/man-rem)	Present worth of 1 man-rem/year for a 40 year reactor life at a discount rate of: D% (£/man-rem/year)		
		D = 0%	D = 5%	D = 7%
0 - 0.5	40	1,600	700	533
0.5 - 1.5	200	8,000	3,500	2,666
1.5 - 5	1000	40,000	18,100	13,332

20 The Inspectorate accepts that it is a reasonable approach for the CEGB to use these monetary values for the purpose of quantifying its judgements as expressed in R646. Further, the sensitivity calculations in respect of the discount rates that might be applied in evaluating the "present worth" of future radiation exposure are accepted by the Inspectorate as a factor to be taken into account by the CEGB in demonstrating that the ALARP requirement has been satisfied. However, the Inspectorate notes the extent to which risk aversion and judgements about the desirability of spending disproportionately more money on reducing high individual doses are included in the NRPB's suggested monetary values. In the Inspectorate's view this means that the monetary values suggested by the NRPB already contain a degree of conservatism which has to be taken into account when deciding on what is "reasonably practicable".

21 On page 8 of R646 the CEGB concludes that "..... the risk due to ORE has been reduced significantly below the balance point of risk and cost". This conclusion is based on the estimated collective dose saving of 135 man-rem/year for Sizewell B compared with the SNUPPS FSAR estimate, taken with an estimate that the dose reducing features of the Sizewell B design have increased the cost of the station by approximately £4M. It is clear from section 9 of R646 that most of

* Tables 1 and 2 are derived from the Tables on pages 7, 8 and 9 of R646, which should be consulted to ascertain the qualifications attached to the values quoted in the Tables.

the important additional dose reducing features of the Sizewell B design benefit those workers who would otherwise have a significant risk of exceeding 1 rem/year and so monetary values equivalent to the higher dose bands, 0.5 - 1.5 and 1.5 - 5 rem, are more appropriate. The CEGB does not provide sufficiently detailed dose budget information in R646 to allow an accurate apportionment to be made between these two bands and in the absence of such information the Inspectorate considers that the cost of radiation-induced detriment is likely to lie somewhere between:

(a) all 135 man-rem in 1.5 - 5 rem/year band: equivalent cost is £5.4M at 0% discount, or £2.4M at 5% discount; and

(b) 50% of 135 man-rem total in 0.5 - 1.5 rem/year band and 50% in 1.5 - 5 rem/year band: equivalent cost is £3.25M at 0% discount, or £1.5M at 5% discount.

22 Given the uncertainties in the estimations, these values are not regarded by the Inspectorate as being significantly less than the estimated £4M spent on dose reducing features. Hence, on the basis of its interpretation of "reasonably practicable" (see paragraphs 6 and 13 above) the Inspectorate does not accept this claim by the CEGB that what it has already done on Sizewell B by way of design improvements compared with SNUPPS is consistent with meeting the ALARP requirement of the Safety Assessment Principles.

CHOICE OF MATERIALS

23 The first of the six options listed in paragraph 11 refers to the choice of primary circuit materials to minimise the formation of crud. As explained in section 4 of R646, the two main contributors to the doses arising from crud are cobalt (Co)58 and Co-60 which are produced by the activation of nickel (Ni)58 and Co-59 respectively. The main source of Ni-58 (and hence Co-58) is likely to be the very large surface area of the Inconel 600 steam generator tubes since Inconel 600 contains 70-75% of nickel. (Contributions from nickel sources in the core region may also play a significant part; the extent of this

contribution is still being evaluated by the Inspectorate). Any significant reduction in the nickel, and hence Co-58, levels would require the use of some different tube material with a lower nickel content and a low release rate. Such a major change is not regarded by the Inspectorate as reasonably practicable, given the other constraints on the choice of steam generator tube material.

24 There is more scope at the present time for the reduction of cobalt levels in reactor materials. Recent studies commissioned by the Electric Power Research Institute, EPRI, (refs 15 and 16) show that the two main sources of cobalt-60 in circuit crud arise from cobalt as an impurity in the Inconel 600 steam generator alloy and as the principal constituent of hard-facing alloy coatings of heavy wear components.

25 On the basis of Canadian and Japanese experience, reductions of the cobalt levels in Inconel 600 from (typically) 0.04W/o to 0.015W/o or less are possible, and such a reduction was partly responsible for a substantial decrease in the radiation dose rates due to cobalt on some CANDU reactors. Thus, in paragraph 4.1 of R646 the CEGB states that the equipment specification for the Sizewell B steam generators requires the tenderer to provide the cost and design implications of reducing the cobalt level in the Inconel 600 tubing from the current average value of 0.04 to a maximum specification of 0.015W/o. The Inspectorate accepts the CEGB's view that to reduce the cobalt specification level below 0.015W/o is not reasonably practicable since further reduction could be disproportionately expensive, even if feasible.

26 The other main source of Co-60 arises from the corrosion-erosion of the stellite hard-facing alloy coatings of heavy wear components, which typically contain 50-60% cobalt. In order to achieve dose reduction the cobalt level in these hard facing alloys can be reduced or alternative materials can be used in which cobalt is only present as an impurity.

27 The CEGB claims in paragraph 4.2 of R646 that the information currently available on the corrosion and wear behaviour of alternative

hard-facing alloys under realistic PWR conditions is limited. The Inspectorate is less pessimistic than the CEGB about the value of the available information but accepts that the CEGB will wish to proceed with caution since maintenance of components which incorporate hard facings is a significant contributor to occupational exposure and the premature replacement of stellite by unreliable alternative alloys could have an adverse effect on safety. Nevertheless, the overseas experience and test results which exist (including those referenced by the CEGB from the Société Française Nucléaire Conference on Hard Facing Materials in Nuclear Power Plants, Avignon, September 1980) could be interpreted as more encouraging than the view expressed in conclusion 2 of paragraph 4.4 of R646, and significant data can be expected in the next two years from UK research programmes. Hence, the Inspectorate will continue to press for frequent reviews of the stellite situation and will expect the CEGB to make provision for changing any relevant valves during the project, where this is shown to be reasonably practicable. In addition, the Inspectorate requires a cost-benefit argument to enable it to judge the extent to which the ALARP requirement has been met.

28 In paragraphs 4.1 and 4.4 of R646 the CEGB comments qualitatively on the reduction of other sources of cobalt inside the reactor pressure vessel, namely:-

(a) the stainless steel used to make the reactor internal structures

(b) the low cobalt alloys which are inside the pressure vessel

(c) the Inconel 713 fuel grids.

Information on the cost effectiveness of reducing the cobalt content in these other parts of the reactor circuit is still awaited from the CEGB. In addition, the CEGB will be required to ensure that plant enquiry specifications include, where appropriate, a requirement to provide costs for lower impurity levels than those currently specified in the United States.

OPERATIONAL CHEMISTRY

29 In section 5 of R646 the CEGB explains that it will make full use of all relevant new information on operating chemistry and the flexibility of the Sizewell B design to adopt a chemical regime which will reduce circuit dose rates as far as reasonably practicable, although at this stage the eventual chemistry has not been specified.

30 The Inspectorate is satisfied with the CEGB's contention that the chemistry parameters for the primary coolant for optimum crud control need not be specified until a relatively late stage, though before commissioning. In the intervening time the CEGB will be expected to perform the necessary research and development to produce the most suitable chemistry regime, relating it to a nickel ferrite base, and including suitable validation from in-pile loop experiments or equivalent sources of data and taking account of worldwide progress. This should include the procedures to be used for preconditioning the circuit surfaces prior to start-up. The Inspectorate will in due course require to be assured of the quality of the operational control and management of chemistry on the reactor, since poor operation could adversely affect crud control.

FILTRATION

31 Once the choice of materials and the operating chemistry of the primary coolant have been defined, the deposition of the resulting activated products on the circuit walls is largely uncontrolled, in the absence of further design provisions. Electromagnetic filtration (EMF) was identified in PWR/R524 (ref 17) and elsewhere (refs 18 and 19) as much the most effective way of controlling deposition, and thus of reducing the circuit crud burden. It is highly efficient at removing the largely ferromagnetic crud particles and should be able to do so at full reactor coolant temperature and pressure, with a reasonable flow rate (eg 0.5% of full flow according to ref 20) through a by-pass circuit. In paragraph 6.2. of R646 the CEGB states that the engineering status of magnetic filters is not in doubt, with prolonged and reliable operation on the boiler circuits of

conventional power plants, on boiling water reactor (BWR) feedwater, and on PWR and BWR blowdown circuits.

32 However, in R646 the CEGB argues against the inclusion of EMF on Sizewell B on the following grounds:

(a) cost of the plant

(b) layout implications

(c) occupational radiation exposure (ORE) implications

(d) technical effectiveness of the plant

(e) the impact on plant safety.

The CEGB's case is discussed under the headings below.

Cost and layout implications, and impact on occupational radiation exposure

33 In paragraph 6.4.1 of R646 the CEGB claims that by far the largest disadvantage of introducing two magnetic filters is the major impact on the layout of the primary containment. The preliminary estimate for the civil works costs is £10M and the EMF plant costs are estimated to be £2.5M, based on the 0.5% full flow design proposal for the Zion nuclear power station in the US. There are no details in R646 about how these costs were arrived at but the Inspectorate is expecting a further report in July 1983 which should provide additional information.

34 As a result of the additional number of welds and valves on Class I pipework needed to accommodate EMF plant, the in-service inspection and maintenance dose for the station is estimated in paragraph 6.4.2 of R646 to be increased by the order of 10 man-rem/year. The dose associated with handling the additional radioactive waste is estimated as 3.5 man-rem/year. If the plant

proposed for Zion collected half of the corrosion products, and assuming that they were the main source of exposure, the overall dose saving, assuming that Sizewell B would otherwise achieve its design ORE of 231 man-rem/year, would be ½ (231) - 13.5 or 102 man-rem/year. In paragraph 6.4.2 of R646 the CEGB then argues that, assuming this reduction was all incurred by staff in the 0.5 to 1.5 rem/year band, the NRPB guidelines would suggest a cost of radiation-induced detriment of the order of £400,000 to £800,000, assuming discount rates of 5% and 0%, respectively.

35 The Inspectorate considers, however, that the assumption that all the 102 man-rem/year would be saved by workers receiving doses in the 0.5 - 1.5 rem/year band is too optimistic. Following arguments similar to those in paragraph 21, the cost of radiation-induced detriment probably lies somewhere between the following:

(a) all 102 man-rem/year in the 1.5 - 5 rem/year band: equivalent cost is £4.1M at 0% discount, or £1.85M at 5% discount

(b) 20% of 102 man-rem/year in the 0-0.5 rem/year band, 35% in 0.5 - 1.5 rem/year band and 45% in 1.5 - 5 rem/year band: equivalent cost is £2.15M at 0% discount, or £1.0M at 5% discount. (The above distribution of collective dose amongst the three dose bands is typical of current experience on large PWRs operating in the US).

36 Thus the cost of radiation-induced detriment suggested by the NRPB guidelines probably lies somewhere between £1M and £4M, compared with the estimated capital expenditure of £12.5M given in R646. Since publishing R646, the CEGB has again addressed the question of space for EMF equipment in its response to the Inspectorate's list of substantial issues (ref 21). Based on the plant sizing considered in previous studies by the industry the CEGB claims that the direct cost of providing space and other necessary engineering features would be about £2M, with a delay to the start of construction of up to 4 months. The CEGB concludes that the cost of providing space is not

likely to be substantial and the Inspectorate considers that this lends support to its position that the provision of space for EMF equipment, at least, is reasonably practicable. A detailed cost and engineering appraisal of EMF plant is expected from the CEGB in July 1983 which will enable the Inspectorate to form a more definitive view on these aspects.

37 To take this point further, the Inspectorate is concerned that, should the collective dose for Sizewell B turn out to be higher than the CEGB's expectation (ie that it will equal the lowest doses experienced on present plants in the US), and be closer to the current US average of 600 man-rem/year, then the cost-benefit analysis would be even more favourable towards installation of EMF. For example, if, as assumed in the CEGB's calculations, about half of such collective dose was saved (ie 300 man-rem), the cost of radiation-induced detriment suggested by the NRPB guidelines would probably lie somewhere in the range £3M to £12M. Thus, solely on the basis of the simple cost-benefit approach adopted in R646, the Inspectorate considers that, in such a situation, the argument that it is not reasonably practicable to include EMF would be difficult to sustain.

Technical effectiveness of the plant

38 Arguments are advanced in paragraph 6.3 of R646 that there are scientific doubts about the value of the deposition velocities, and hence half-lives, of the PWR crud particles which leave considerable uncertainty about the size of the EMF plant that would be necessary to compete with circuit wall deposition. The CEGB cites recent French data (ref 22) in support of its claim that the half-life is very short. This conflicts with studies by Westinghouse and others (see ref 20) which indicate a much longer half-life. The value of the deposition half-life is related to two observable parameters, namely the concentration of suspended crud in the coolant and the mass of crud on the circuit walls. Given the observed relatively constant value of the former, a very short deposition half-life would suggest a much greater burden of crud on the walls than is found in practice. Furthermore, the Inspectorate understands that preliminary results

from extensive particle behaviour studies carried out by the UKAEA on an operating PWR indicate that there may be strong reasons for believing that the deposition velocities are in the range which would give support to the view that the effectiveness of a full scale EMF plant is not seriously in question. Indeed, there is some evidence (ref 19) which indicates that the reduction in crud levels and doses may turn out to be significantly greater than the two-fold reduction assumed in R646.

39 In view of this the Inspectorate does not consider that the CEGB has made a sufficient case to support its contention that the scientific uncertainties are reason for justifying the omission of space for EMF plant, and for questioning the effectiveness of the method for reducing crud levels. A further submission from the CEGB is awaited which, with the above-mentioned cost and engineering appraisal, should enable the Inspectorate to reach a firmer view on this issue.

Impact on plant safety

40 In R646 the CEGB states that the extension of the primary circuit pressure boundary and the connections for the EM filtration plant could contribute to an increase in the risk of a LOCA occurring, but that this increase is not quantifiable. There is also a potential risk that particles released from the filter matrix could lead to core blockage. Neither of these aspects has been included in the EMF cost-benefit arguments but will need to be taken into account when the further submission is available.

Overall position

41 The Inspectorate considers that, if Sizewell B behaved according to the CEGB's expectations and if the monetary costs were as quoted in R646, the inclusion of EMF plant would not be reasonably practicable. However, recent CEGB information (ref 21) indicates that the cost may be substantially less than the amount quoted in R646 and this lends support to the Inspectorate's position that the provision of space for

EMF equipment is reasonably practicable. Further, the Inspectorate considers that many factors may arise which could cause the station collective dose to increase substantially above the CEGB's present expectations, especially as the plant ages. Unless this can be shown not to be the case, it is the Inspectorate's view that it would be difficult, on the basis of cost-benefit analysis alone, to argue that it was not reasonably practicable to include EMF plant. However, it needs to be emphasised that these comments only relate to the rudimentary cost-benefit arguments presented in R646. There are other factors, such as the arguments about "untried technology" and the increased risks of LOCAs, which the Inspectorate will have to take into account, before reaching a firm decision on whether or not EMF plant should be included in the Sizewell B design.

DECONTAMINATION

42 The CEGB's strategy presented in section 12.3.5 of the PCSR for the chemical decontamination of the whole primary circuit was broadly acceptable to the Inspectorate. This involved an extensive research and development programme to establish and validate a suitable process, for which two candidates were presented as leading options, and a commitment to provide the necessary space and residual heat removal system (RHRS) pipe stubs in the design (see paragraph 12.11 of the Review). Since then, these stubs and the required space have apparently been deleted which changes the Inspectorate's view of the matter. According to PWR/R524 (ref 17), such connections are necessary to enable whole-circuit decontamination to be performed. The CEGB has been asked to clarify and justify its apparent change of position because the Inspectorate needs to be assured that the option of whole-circuit decontamination is still available in the Sizewell B design since in R646 it is stated that the indications from laboratory tests are that a reduction in radiation fields of a factor of greater than two is potentially available from whole-circuit decontamination.

43 The Inspectorate has also noted that while the CEGB's presently-favoured decontamination processes LOMI (Low Oxidation State Metal Ion reagents) and POD (PWR Oxidative Decontamination) are said to give

good decontamination factors for stainless steel surfaces, such as the reactor coolant pipework and pumps, there seems to be a fundamental problem, in common with other reagents, of decontaminating Inconel 600 surfaces (eg steam generator tubes, tube-sheets and divider plates) to a similar degree. The Inspectorate accepts that there is much scope for research and development work to resolve the difficulty, but on the information currently available is unable to judge the extent to which a decontamination process could effectively reduce radiation levels.

44 In paragraph 7.6 of R646 the CEGB concludes that as there is, at present, no suitably-proven process for full-circuit decontamination of PWRs such as Sizewell B it is not possible to design and size the associated chemical plant, nor make an estimate of the associated cost, nor carry out a detailed estimate of the radiation-induced detriment saved which must take into account waste arisings and their processing.

45 The Inspectorate notes this conclusion but considers that no arguments have been advanced in R646 which would support the exclusion of whole-circuit decontamination as a viable future option for controlling radiation levels on Sizewell B. The Inspectorate also considers that, even allowing for the uncertainties about the eventual process that may be used, a meaningful attempt could have been made in R646 to quantify the additional waste management facilities that would be needed to handle the waste arisings from whole-circuit decontamination. Such information is not provided and this deficiency has a significant bearing on the conclusions reached about the size of the Solid Waste Management System (SWMS).

DESIGN MODIFICATIONS

46 In section 8 of R646 are discussed the design modifications affecting plant layout which the CEGB has considered for the Sizewell B design. These are:

(a) provision of a narrow cavity for the reactor;

(b) provision of a reactor pressure vessel head laydown shield;

(c) provision of a reactor pressure vessel head parking area shield;

(d) segregation of the residual heat removal (RHR) pipework and auxiliary system heat exchangers in the containment;

(e) shielding of the reactor pump motor compartment and the provision of permanent man-access features in the primary loop cells;

(f) provision of an increase in containment diameter.

The Inspectorate accepts that these design modifications, together with those discussed in Chapter 12 of the PCSR, particularly in section 12.3.5, are the main items where application of the ALARP requirement would be of concern.

Narrow reactor cavity

47 The main advantage of a wide reactor cavity, as in SNUPPS, is that it gives easier access to the reactor pressure vessel and its penetrations for in-service inspection. Its disadvantage is that it is easier for radiation to stream up the gap to the area around the pressure vessel flange, where a considerable amount of work is carried out when the reactor is refuelled. Conversely, a narrow reactor cavity makes in-service inspection from the outside of the vessel more difficult but reduces the doses received during refuelling and maintenance of the reactor pressure vessel head.

48 In arriving at the decision to adopt a narrow cavity design for Sizewell B the following five considerations were investigated by the CEGB:

(a) the ability to inspect the RPV in-service

(b) the RPV insulation and cavity cooling

(c) venting requirements under LOCA conditions

(d) the impact of refuelling procedures and associated occupational exposure.

(e) cost implications.

49 According to the CEGB in R646, the design choice is not limited by considerations (b) or (c). The inhibition of ultrasonic inspection from the outside of the reactor pressure vessel, which arises from adoption of the narrow cavity design, is discussed in NII 01 (Supp 10) (ref 23). In Supplement 10 the Inspectorate accepts the CEGB's undertaking that all those components which need to be removed to facilitate ultrasonic inspection of the nozzle-to-shell welds from the outside, including the insulation around the nozzles and welds, will be designed to be readily removable so as to reduce the doses that might be incurred if supplementary inspections needed to be performed from the outside.

50 No estimate is given in R646 of the in-service inspection dose burden associated with the change from a wide to a narrow cavity, although it is anticipated that the above undertaking should help to make it small. The only impact on the occupational radiation exposure (ORE) which is assessed by the CEGB is that due to refuelling procedures, for which it is claimed that adoption of the narrow cavity design leads to a reduction in ORE of between 12 and 20 man-rem per single refuelling, depending on the plant age. At 5% discount rate, 20 man-rem per year has a present worth of £360,000 (assuming the NRPB value for the 1.5 - 5 rem dose range); at 0% discount rate the equivalent figure is about £800,000.

51 The estimated cost implication of going from a wide cavity design to a narrow cavity design is £500,000 and therefore the CEGB considers that a narrow cavity is justified on the basis of the above figures. The Inspectorate accepts the CEGB's case that there is an overall

benefit to the protection of the station staff from the adoption of a narrow cavity design.

RPV head laydown shield

52 The provision of an RPV head laydown shield not only leads to an estimated reduction of 3 man-rem/year but also protects the operators from dose rates of up to several rem/hour. As there are no particular disadvantages, this provision is acceptable to the Inspectorate.

RPV head parking area shield

53 In R646 the CEGB claims that it is difficult to quantify the occupational dose saving of this feature, but estimates that it might be 1 to 2 man-rem/year. It has been included in the Sizewell B design, at an estimated cost of £50,000, although, as explained in R646, the reasons for its inclusion went beyond a simple consideration of the cost-benefit arguments. Again, as there are no particular disadvantages associated with this feature, it is acceptable to the Inspectorate.

Segregation of RHR pipework and auxiliary system heat exchangers in the containment

54 In R646 it is stated that there are several important arguments against providing this segregation which, it is claimed, would mean a substantial change to the layout of the whole station at an estimated cost in excess of £10M.

55 As the RHR pipework and auxiliary system heat exchangers are located at different levels the Inspectorate is not convinced that such a complete station redesign is necessary to achieve the desired segregation. At the same time the Inspectorate accepts that the estimated dose incurred while erecting the temporary shielding to compensate for the absence of segregation is relatively small at 3 man-rem/year. Using the NRPB figures for the 1.5 - 5 rem dose range the cost of radiation-induced detriment would be between £54,000 (5%

discount) and £120,000 (0% discount), well below the estimated cost of £10M, and consequently the CEGB has decided not to provide segregation.

56 The Inspectorate has asked the CEGB to explain in more detail the reasoning which supports its view that such a costly redesign is necessary to provide the required segregation, rather than treating each item separately. This submission is still awaited.

Shielding of the reactor pump motor compartment and the provision of permanent man-access features in the primary loop cells

57 These provisions would help to reduce the exposure of operators during maintenance work in dose-rate fields which give a significant chance of personnel receiving an individual dose in excess of 1 rem/year. The estimated dose saving would be 10 to 11 man-rem/year, which on NRPB's figures is worth £180,000 - £200,000 (5% discount) or £400,000 - £440,000 (0% discount). The estimated cost of providing the necessary shielding and permanent platforms is £400,000 and, provided the features can be shown to be compatible with the LOCA venting requirements, the Inspectorate considers their inclusion is reasonably practicable.

Increased containment diameter

58 The internal radius of the Sizewell B primary containment has been increased by 1.5 m compared to SNUPPS at an estimated cost in excess of £15M. The increase, which was largely necessary to provide the additional space required for safety-related plant, should have a beneficial effect on the dose received during operations within the containment owing to improved access and the additional flexibility provided for handling equipment. However, the CEGB has made no attempt to estimate the dose reduction associated with increasing the containment diameter. This is acceptable since the cost of increasing the containment diameter is not primarily associated with dose reduction considerations.

DESIGN MODIFICATIONS AIMED AT REDUCING THE WORKING TIME IN RADIATION FIELDS

59 In radiological protection, the Inspectorate expects priority to be given by the CEGB to the reduction of sources of radiation so far as is reasonably practicable before introducing special provisions or placing controls on individuals to reduce doses. However, should high dose rates persist in areas of the plant to which access is required for refuelling, maintenance or inspection then there will be a need for remotely-operated equipment to reduce the access times. In section 9.1 of R646 the CEGB deals with such design modifications and these are discussed below. The Inspectorate accepts that these design modifications, together with those discussed in Chapter 12 of the PCSR, particularly in section 12.3.5, are the main items where application of the ALARP requirement would be of concern.

Provision of steam generator robots

60 Even when all reasonably practicable measures have been taken to control crud, and hence reduce dose rates from the primary circuit, it may still be necessary for the CEGB to incorporate additional design provisions aimed at reducing the doses to station staff even further. Potentially one of the most effective of such methods is to perform all the necessary steam generator tube bundle eddy current (EC) inspection and maintenance (including plugging of any defective tubes), and all the ultrasonic inspection of the channel head welds, remotely using a robotic device especially designed for the task. Such equipment is currently under development; for example, Westinghouse are developing a Remotely Operated Service Arm (ROSA). The projected cost for the system employing one ROSA unit is £300,000.

61 It is claimed in R646 that a device such as ROSA could save an estimated 70 to 80 man-rem/year on a typical Westinghouse four loop plant in the US while a less sophisticated device (the Technisch Bureau Vermaat (TBV) manipulator) could save approximately 60 to 70 man-rem/year on a four loop plant. On that basis, the incorporation of a system such as the ROSA system appears to be cost effective.

62 However, very high dose rates are expected around the steam generator channel heads (of the order of 10 rem/hour). The Inspectorate is concerned that, should the proposed equipment fail to perform as expected, unplanned prolonged entry into these high dose rate areas would become necessary, which would make the control of doses to individuals very difficult. The CEGB claims in R646 that "the ROSA system is in an advanced state of development and it is anticipated that it will be used for the first time on site before the end of 1982". The CEGB has been asked to provide the information required to substantiate the claims made regarding remotely-controlled equipment for inspection and maintenance of the steam generators; this information has not yet been provided. Such information is required by the Inspectorate at an early stage of the project so that it can have confidence that suitable equipment of proven reliability will be available when the time comes for the CEGB to make a final decision on steam generator inspection and maintenance equipment.

Use of a multi-stud tensioner (MST) for the RPV

63 The CEGB estimates in paragraph 9.1.2 of R646 that the cost differential between a multi-stud tensioner and the Westinghouse system of single stud tensioning and removal is £400,000. The corresponding dose saving to operators is expected to be 8 man-rem/year. Hence, the CEGB argues that the cost of radiation-induced detriment in itself would not justify the provision of an MST. However, an MST will be utilised at Sizewell B, both because of its considerable operational benefits and because it will significantly reduce the risk of an individual dose exceeding 1 rem/year. As there are no significant disadvantages associated with this design feature, it is acceptable to the Inspectorate.

Provision of an Integrated Head Assembly

64 In R646 the CEGB estimates that this equipment will save 4 man-rem every refuelling outage, at an additional cost of £50,000. It has been included in the Sizewell B design for the same reasons as those related to the MST and is acceptable to the Inspectorate.

Provision of a SIGMA (Single Integrated Gripper/Mast Assembly) refuelling machine

65 This equipment is estimated in R646 to save 3 - 5 man-rem/year, at an additional cost of £150,000. It has been included in the Sizewell B design because of its operational advantages and the reduced risk of individual doses exceeding 1 rem/year. This is acceptable to the Inspectorate.

Permanent guide studs for the RPV

66 It is claimed in R646 that provision of permanent guide studs would save approximately 1 man-rem on the annual refuelling dose. Against that, the CEGB estimates that additional stress work and inspection together with, for example, the extra material, would add approximately £90,000 to the cost of the vessel, but it is difficult to estimate the additional costs associated with the redesign of the standard Westinghouse lifting rigs and other associated equipment. However, it is argued that on the basis of the above estimate alone, which is accepted by the Inspectorate, this feature is not cost effective and, in view of the levels of individual dose involved, the Inspectorate accepts the design decision not to include permanent guide studs on Sizewell B.

Provision of a "quick-opening" fuel transfer tube closure

67 It is estimated that this provision will save a dose of between 0.3 and 1 man-rem/year at a cost of about £10,000. The CEGB regards this feature as cost beneficial since, without it, operators would need to work for one or two hours in an environment that could have dose rates as high as 3 rem/hour. The Inspectorate accepts the design decision to incorporate this provison.

One-piece reactor coolant pump bowl

68 The SNUPPS pump bowl is fabricated from austenitic stainless steel castings and the fabrication welds require volumetric inspection

in-service, which necessitates removal of pump internals. In R646 the CEGB states that a single piece cast bowl is most likely to be chosen for Sizewell B and claims that, although the use of a pump with a single piece cast bowl would still necessitate removal of pump internals for visual inspection of the internal surfaces, it would avoid lengthy inspections in radiation fields of approximately 300 mrem/hour and so should lead to a significant reduction in ORE. However, the Inspectorate has expressed concerns in NII 01 (Supp 11), (ref 24), about the CEGB's current proposals for in-service inspection of the coolant pump bowls. In view of these reservations, the Inspectorate considers that the dose savings from reduced inspection requirements, as claimed in R646, are in doubt.

Use of multi-stud tensioners for the steam generator manways

69 Equipment is available which is suitable for the remote handling and removal of the manway cover on the steam generator. The typical cost of such a unit as used on European plants is £60,000 and in R646 the CEGB anticipates that two such units would be needed for Sizewell B at a cost of £120,000. The dose saving would be of the order of 3 - 4 man-rem/year. Although the CEGB estimates that the equipment cost exceeds the cost of radiation-induced detriment as given in the guidelines of Section 3 of R646, it would significantly reduce the risk of the individual dose exceeding 1 rem/year. The use of this equipment is acceptable to the Inspectorate.

Automatic ultrasonic scanners for circumferential welds

70 Although in R646 the CEGB estimates that the use of ultrasonic scanners could save up to 4 man-rem/year, no indication is given of the cost of such equipment. Hence, the Inspectorate cannot judge whether or not it is reasonably practicable. Further information is required from the CEGB to show that the extent of automatic scanning chosen is the most that is reasonably practicable.

EQUIPMENT DESIGN MODIFICATIONS AIMED AT REDUCING DOSE RATES

71 The CEGB discusses in section 9.2 of R646 the following two equipment design modifications which are aimed at reducing the dose rates in areas to which access is required:

(a) deletion of the resistance temperature detector bypass manifold, and

(b) provision of a dedicated system to clean the refuelling pool water.

The Inspectorate accepts that these equipment design modifications, together with those discussed in Chapter 12 of the PCSR, are the main items where application of the ALARP requirement would be of concern.

Deletion of the resistance temperature detector (RTD) bypass manifold

72 On SNUPPS, reactor power levels are monitored using temperatures derived from the flow through dedicated RTD bypass manifolds, one on each of the four loops. The RTD manifold and associated valves trap crud and have also required extensive maintenance on operating plants. This has contributed a significant amount to the station collective dose. An alternative system is available which is based on the measurement of nitrogen-16 activity in the coolant. Replacement of the RTD system by nitrogen-16 power monitors is estimated to save approximately 8 man-rem of the annual dose and will cost £10,000. The Inspectorate finds the use of this equipment acceptable.

Provision of a dedicated system to clean the refuelling pool water

73 The Sizewell B reference design includes a dedicated system for cleaning the refuelling pool water. In R646 the CEGB estimates that the average dose savings are unlikely to exceed 1 or 2 man-rem per refuelling, but some operational and dose benefit may be expected from reduced fuel shuffling times due to improved water clarity. However, the cost of this system is estimated to be £1M which, by comparison

with the NRPB figures, is considerably in excess of the cost of the radiation-induced detriment. Hence its provision is being reviewed by the CEGB.

74 The Inspectorate accepts that the provision of a dedicated system to clean the refuelling pool water should be reviewed to assess its cost effectiveness, but will expect to see the details of a cost-benefit analysis, which includes the potential benefits and in particular quantifies the activity removed, such as Co-58 and Cs-137, before a decision is taken by the CEGB to delete this provision from the design.

RADIOACTIVE WASTE MANAGEMENT

75 In section 13.2 of the Review it was stated that, as far as waste management is concerned, the application of the ALARP requirement implies, in addition to the need to minimise doses which might be received, the need to arrive at a suitable balance between the dose received by station staff from waste treatment and temporary storage on-site, and the dose received by members of the public from wastes discharged from the site. In this area there is joint responsibility between the Authorising Departments (DOE and MAFF) and the Inspectorate.

76 The systems model of the radioactive waste management plant is described in chapter 11 of PCSR. These are the systems proposed for collecting, processing, storing and discharging radioactive wastes. There are three basic physical types of radioactive wastes; gaseous, liquid and solid. The engineering systems provided reflect this natural division and are described individually below.

The liquid waste management system (LWMS)

77 The CEGB's initial design appraisal study (see section 10.2.1 of R646) examined four alternative LWMSs in terms of their capital cost and the associated activity discharged to the sea. This work was later extended to include an occupational dose assessment for each LWMS.

78 The four alternative options considered in the initial study are detailed in Table 4 of R646; their main features are as follows:

System 1: filter, monitor and discharge all liquid waste streams immediately without further treatment.

System 2: hold-up high active waste streams for 30 days, then filter, monitor and discharge.

System 3: hold-up high active waste streams for 20 days, then evaporate, monitor and discharge.

System 4: hold-up high active waste streams for 30 days, then treat via a two-stage ion exchange process, monitor and discharge.

(For systems 2, 3 and 4 the low active waste streams are filtered, monitored and discharged immediately without further treatment).

79 However, Table 4 does not contain details of the actual system proposed by the CEGB for Sizewell B. In discussions with the CEGB the Inspectorate was informed that the final design is likely to be a modified version of system 2 as given in Table 4 but a proper case, and detailed description of the design, is still awaited by the Inspectorate before a full assessment can be carried out.

80 Also from its discussions with the CEGB the Inspectorate understands that the estimated collective dose to the UK population from the LWMS design option likely to be chosen is 3.2 man-rem/year and the estimated maximum individual dose to the most exposed member of the public within the critical group is 8 mrem/year. The maximum individual dose to other members of the public outside the critical group is estimated to be less than 5 mrem/year. At this level of annual dose, 3.2 man-rem/year is equivalent to an implied capital cost of between £1500 and £2500, at discount rates of 3% and 0% respectively. Even if the very pessimistic assumption were made that

the 5-50 mrem/year dose band should be used, the cost of radiation-induced detriment would only be between £7,400 and £13,000, for 3% and 0% discount rates.

81 It is argued in section 10.2.2.1 of R646 that such low public exposure values could not be reduced further in a cost effective manner. The Inspectorate and the Authorising Departments have requested that Table 4 of R646 should be completed to show the public exposure and ORE values for the actual design option chosen, as well as the public exposure figures for the other design options in Table 4. Only when such information is available will it be possible to assess whether the selected design option achieves the best balance between operator exposure and public exposure.

82 Nevertheless, at this stage the Inspectorate agrees with the DOE's position (ref 25) that the conclusions presented in section 10.2.3 of R646 reflect current practice in the nuclear industry in the UK, even though current UK plants are of a different type. The Inspectorate and the Authorising Departments will review this conclusion in the light of the further information which the CEGB has promised.

The gaseous waste management system (GWMS)

83 In paragraph 10.3.1 of R646 it is stated that, in the initial design appraisal study, a number of methods of treating the high activity gaseous waste stream were considered including schemes which employed a continuous hydrogen purge of the gas space of the Volume Control Tank (VCT) and other techniques where this operation is carried out intermittently. The chosen option involves continuous VCT purge which has the advantage that the gaseous fission product content of the primary coolant is minimised thereby reducing the quantity of gaseous activity that can leak into the general atmosphere of the station buildings.

84 The basic difference between the current Sizewell design and the SNUPPS design is that, for Sizewell B, gaseous waste will not be

stored on site for the lifetime of the station. The Sizewell proposal is that the accumulation and storage times will each be 45 days. On the basis of these accumulation and storage times it is estimated in R646 that the resulting individual dose at the site boundary, assuming 100% occupancy, is less than 1 mrem/year due to fission products. The associated collective dose to the UK population is estimated to be approximately 0.1 man-rem/year due to fission products (including tritium), with a further 9 to 10 man-rem/year attributable to the emission of carbon-14. However, as C-14 has a half life of 5700 years its contribution to the collective dose is not materially different whether the active gases are released after 45 days storage or after 40 years.

85 With such a small contribution to the collective dose from fission products, the use of NRPB's figures would suggest only a small sum to be spent on reducing the collective dose below the 0.1 man-rem/year figure given in R646 (of the order of a few hundred pounds at most). Such a sum would be quite insignificant in comparison with the capital cost that would be required to effect a meaningful reduction in the gaseous fission product release from the station. However, there may be other considerations which would need to be taken into account by the Authorising Departments and the Inspectorate in assessing the GWMS for Sizewell.

86 The proposed GWMS, involving continuous gas purging of the VCT and the provision of a 45 day accumulation and storage system, appears to achieve not only a very low collective dose to the public but also a low ORE and so is considered by the Inspectorate and the Authorising Departments to achieve a generally acceptable balance between operator exposure and public exposure. Nevertheless, it is considered that the omission of two decay tanks has not been adequately justified. A further submission is required from the CEGB on this matter.

The solid waste management system (SWMS)

87 The Sizewell B solid waste management system (SWMS) is intended to meet CEGB and UK waste management strategy and policy. It is

similar to the SNUPPS design in many respects, the main differences being:-

(a) the proposal to burn active oil on site rather than transport it off-site for land burial as in the US,

(b) the use of an on-site incinerator to reduce the volume of low activity solid waste for the Sizewell plant,

(c) the possible use of sea dumping for intermediate activity wastes, and

(d) the provision of a solidification plant for Sizewell B which is capable of using a range of matrices, and not just cement as on SNUPPS.

88 There are no cost-benefit arguments provided in R646 to show that the SWMS chosen for Sizewell B achieves the lowest reasonably practicable exposure. This is acceptable for the public because the aim of the controls exercised during the handling of solid waste is to ensure that there is no spread of radioactivity off the site and that the associated direct radiation levels are negligible. However, the Inspectorate requires a cost-benefit analysis to show that the chosen SWMS achieves the lowest reasonably practicable exposure of the operators.

89 The SWMS will be kept under review by the Inspectorate, in consultation with the Authorising Departments, as the detailed design of the system is developed by the CEGB and solid waste will be required to be controlled by the CEGB in such a manner that no member of the public receives a significant exposure therefrom.

90 The Inspectorate will require the CEGB to make quantitative estimates of the additional radioactive wastes that will need to be handled should whole-circuit decontamination prove necessary. It is difficult to make accurate estimates of the likely arisings when the decontamination process has not been decided, but the Inspectorate

considers that scoping calculations can be carried out for the procedures currently envisaged as possible. Such calculations are required to support the CEGB's claim that the waste processing plant would be adequate to deal with the wastes arising from whole-circuit decontamination. They would also have a bearing on the cost/benefit arguments related to whole-circuit decontamination.

Overall position

91 The Inspectorate is satisfied, with the exception of the matters referred to in paragraphs 81, 86, 88 and 90 above, that the solid, liquid and gaseous waste management systems described in the PCSR are likely to be sufficiently flexible to allow a proper balance to be achieved between the exposure of on-site workers and the general public, each being as low as reasonably practicable.

SUMMARY AND CONCLUSIONS

92 In its report R646 the CEGB has made a significant attempt to quantify the design decisions which have been taken on Sizewell B in respect of ensuring that the exposure of persons to ionising radiation is as low as reasonably practicable. It is the most comprehensive study carried out to date for any nuclear power plant in the UK and provides much valuable information on the benefits and costs of various options and allows their relative impacts to be assessed. It is not a complete cost-benefit analysis of the whole system since each option is studied in isolation without reference to its impact on other options (for example, there is no consideration of the impact of reducing the cobalt level in the Inconel 600 steam generator tubes on the possible need for electromagnetic filtration equipment, and so on). Also the "costs" are usually limited to the capital costs of the relevant equipment (ignoring other costs associated with such things as possible operational delays and increases in the likelihood of faults) and the "benefits" are generally only evaluated in terms of collective dose saved (without any reference, for instance, to factors such as operational convenience). However, the Inspectorate recognises that such a complete cost-benefit analysis would be very

expensive to perform and may not even be feasible given the current state of knowledge of the plant design and the techniques of cost-benefit analysis involved. Furthermore, the conclusions from cost-benefit analysis should not automatically determine decisions since there will be other considerations which may not be quantifiable in monetary terms which need to be taken into account. Examples of such other considerations are the working environment, the maximum dose rates which the workers may experience (the Inspectorate considers that work in high dose rate fields, ie greater than about 100 mrem/hour, requires special justification because of the increased chance of overexposure incidents and the difficulty of exercising proper radiological control), effects on plant which have a safety impact in other areas such as protection equipment, detailed engineering aspects of the design, and the cumulative exposure of the workers involved. Such matters as these are not discussed in R646 but are in part described in the design measures to reduce the ORE presented in the PCSR, in particular in Chapter 12. Others will be given attention during operation. Hence, it is important to appreciate that cost-benefit analysis is not a substitute for proper judgements in decision making but is a useful aid to such judgements. Notwithstanding this, the Inspectorate would make the following points in the light of the cost-benefit analysis reported in R646.

93 On the basis of its interpretation of the ALARP requirement the Inspectorate does not accept the CEGB's argument that what has already been done on Sizewell B by way of design improvements compared with SNUPPS necessarily satisfies this requirement (para 22).

94 The Inspectorate does not consider that the CEGB, in attempting to achieve its design objective, has made a sufficient case for not keeping open the option of EMF. This option holds the promise of reducing crud in the primary circuit pipework and components and hence reducing the high dose-rates experienced in certain areas of the plant. As pointed out in paragraph 92 above the Inspectorate gives special weight to the need to reduce high dose-rates in its ALARP judgements.

95 The Inspectorate does not consider that the CEGB has made a sufficient case to support its contention that the scientific uncertainties are sufficient justification for the omission of space for electromagnetic filtration plant. Nor do the uncertainties provide support for questioning the effectiveness of the method for reducing crud levels (para 39).

96 Recent CEGB information indicates that the cost may be less than the amount quoted in R646 and this lends support to the Inspectorate's position that the provision of space for EMF is reasonably practicable. Further, the Inspectorate considers that many factors may arise which could cause the station collective dose to increase substantially above the CEGB's present expectations, especially as the plant ages. In such circumstances the Inspectorate is not convinced, solely on the basis of the cost-benefit analysis so far provided by the CEGB, that it is not reasonably practicable to include EMF plant (para 41). This is identified as issue A11 in NII/S/60(Saf).

97 The Inspectorate accepts that it is not reasonably practicable for the CEGB to change the steam generator tube material from Inconel 600 to a material with a lower nickel content and a low release rate (para 23).

98 The Inspectorate accepts that it is not reasonably practicable for the CEGB to reduce the cobalt specification in the steam generator tubes below 0.015W/o, since further reduction could be disproportionately expensive, even if feasible (para 25).

99 With respect to hard-facing materials, the Inspectorate will continue to press for frequent reviews of the stellite situation and will expect the CEGB to make provision for changing any relevant valves during the project, where this is shown to be reasonably practicable (para 27).

100 The Inspectorate is satisfied with the CEGB's contention that the choice of chemistry parameters for the primary coolant for optimum crud control need not be specified until a relatively late stage, though before commissioning (para 30).

101 The Inspectorate requires to be assured before licensing that the option of whole-circuit decontamination is still available for Sizewell B since the CEGB indicates in R646 that a reduction in radiation fields of a factor of more than 2 is potentially available from such a procedure (para 42).

102 The Inspectorate also considers that, even allowing for the uncertainties about the eventual process that may be used, the CEGB should have made an attempt in R646 to quantify the additional waste management facilities that would be needed to handle the waste arisings from whole-circuit decontamination (para 45).

103 The Inspectorate accepts that there is a net positive benefit to the protection of the station staff from the adoption of a narrow reactor cavity design (para 51).

104 The Inspectorate accepts a number of other design modifications which are aimed at reducing the dose to workers on the plant (paras 52, 53, 63, 64, 65, 67, 69, and 72).

105 Concerning the segregation of RHR pipework and auxiliary system heat exchangers in the containment, the Inspectorate is still awaiting a submission from the CEGB to explain in more detail the reasoning which supports its view that a costly redesign is necessary to provide the required segregation, rather than treating each item separately (para 56).

106 The Inspectorate considers that, provided the LOCA venting requirements are met, the inclusion of shielding of the reactor pump motor compartment and the provision of permanent man-access features in the primary loop cells are reasonably practicable (para 57).

107 The Inspectorate accepts the potential for a considerable dose saving from the use of a robotic inspection and maintenance system for the steam generators but has asked CEGB for information to substantiate the reliability of such equipment (para 62).

108 On the basis of the small estimated dose savings, the Inspectorate accepts the design decision not to include permanent guide studs for the RPV (para 66).

109 Since no indication is given in R646 of the cost of providing automatic ultrasonic scanners for circumferential welds the Inspectorate cannot judge whether or not it is reasonably practicable. This should be provided before licensing (para 70).

110 The Inspectorate accepts that the provision of a dedicated system to clean the refuelling pool water should be reviewed to assess its cost effectiveness, but will expect to see a detailed cost-benefit analysis, which includes all potential benefits, before a decision is taken by the CEGB to delete this provision from the design (para 74).

111 At this stage, the Inspectorate accepts that the LWMS design option chosen generally reflects current practice in the nuclear industry in the UK. The Inspectorate, and the Authorising Departments, will review this conclusion in the light of further information to be provided by the CEGB, in order to be satisfied that the best balance has been achieved between operator exposure and public exposure and that doses have been reduced as far as reasonably practicable (para 82).

112 The Inspectorate considers that the proposed GWMS is likely to achieve an acceptable balance between operator exposure and public exposure. The omission of two decay tanks needs to be justified (para 86).

113 There are no cost-benefit arguments in R646 to show that the SWMS achieves the lowest reasonably practicable exposure of the operators. The Inspectorate, in consultation with the Authorising Departments, will continue to assess the SWMS as the detailed design becomes clearer and will require evidence that the eventual system achieves the lowest reasonably practicable exposure of operators and has the capacity to handle the wastes arising from possible whole-circuit decontamination (paras 88-90).

114 The Inspectorate is satisfied, with the exception of the specific matters mentioned in this report, that the waste management systems described in the PCSR are likely to be sufficiently flexible to allow a proper balance to be achieved between the exposure of on-site workers and the general public, each being as low as reasonably practicable (para 91).

HMNII
July 1983

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