October 25, 1982

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FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: SIZEWELL B - ANALYSIS OF BRITISH APPLICATION OF U.S. PWR TECHNOLOGY

Purpose

To initiate and provide direction for an NRR review of the major issues raised by the British in their application of PWR technology and of the design changes that resulted from this application.

Background

The Central Electricity Generating Board (CEGB) of Great Britain recently applied to its Secretary of State for Energy for approval to build a nuclear power station at Sizewell in Suffolk, England. The Nuclear Installations Inspectorate (NII) is in the process of reviewing this application and will begin a public inquiry early in 1983. The Sizewell "B" reactor, which will be the first British nuclear power station to employ a PWR design, will be similar to the Westinghouse SNUPPS reactor design. The design of the Sizewell "B" plant contains several safety related systems that differ significantly from SNUPPS. Further, NII has identified certain areas where they are dissatisfied with the application or where they required further information. Accordingly, it has been decided that a review of the Sizewell "B" design differences from SNUPPS and the NII findings on the design be performed by NRR so that the differences between the U.S. and British PWR reactor practice and acceptance criteria are identified and the basis for their adoption understood.

Action

Enclosure 1 is a list of open and major confirmatory issues raised by NII during its review of Sizewell and of major design changes to the SNUPPS design made by CEGB prior to submittal. The indicated divisions are to prepare a difference analysis on each issue and design change listed in Enclosure 1. The analysis should follow the format of Enclosure (2), should address the following:

(1) A detailed technical description of the design change or issue.

(2) A description of the equivalent design or position taken in the SNUPPS applications.

(3) A detailed technical description of the basis on which NRR found the equivalent SNUPPS feature adequate. } NRC Criteria

(4) An analysis of the safety benefits the CEGB change was intended to achieve or of the safety concerns underlying the NII open issue.

(5) Questions on detail or requests for further information to be put to the British.

Division directors are strongly encouraged to review those portions of the British docket in their area of responsibility to identify other important areas to be explored similarly. An analysis of these should be prepared on the same schedule.

This review and analysis is a high priority effort. Given the short schedule and interdisciplinary nature of many of the issues the effort is likely to require senior level individuals. Conflicts in schedule and resource commitment between this and other efforts should be brought to D/PPAS thru Ed Goodwin for resolution.

Future Effort

When these analyses are complete, they will be reviewed by an ad hoc group consisting of S. Hanauer, R. Bernero, T. Novak, H. Faulkner, and E. Goodwin. This group is to identify those most important issues deserving detailed exploration with the British during a technical exchange visit in December and to identify the members of the NRR exchange team.

After the exchange, a detailed report is to be prepared.

Management

The overall NRR effort is to be coordinated by E. Goodwin of PPAS. The day-to-day management and support of the review effort is to be managed by DL. The technical review, paper flow, scheduling, communications, and resource management are to be handled exactly as are SER inputs. G. Edison, LB-1, is to be Project Manager. Dr. Edison is to open a TAC number, monitor schedule and resource expenditures for this effort, coordinate the technical reviews, and prepare the report.

Scheduling

-	Reviewers identified to PM	10/27
-	Briefing for reviewers and management	10/29
-	Additional topics identified by divisions	10/29
-	Draft analysis input to PM	11/15
-	Visit agenda prepared, issues identified	11/19
-	Exchange team identified	11/19
-	Final analysis to PM*	11/22
-	Team briefed by reviewers	11/22
-	Final analysis to team	11/29
-	Visit to UK	12/6-10
-	Input to final report due*	1/14/83
-	Report ready in draft	1/28/83
-	Final report published	2/25/83

* Typed input from AD to T. Novak with copies to G. Edison and B. J. Youngblood.

References

NRR has obtained a copy of fundamentally the entire CEGB submittal. It consists of the following:

- UK Sizewell B Reference Design
- CEGB Pre-construction Safety Report
- CEGB Statement of Case
- CEGB Probabilistic Safety Study (WCAP 9991)
- UKAEA Degraded Core Analysis
- NII Safety Assessment
- Associated Documents

Copies are held as follows:

- Each division director
- G. Edison
- E. Goodwin
- A. Thadani
- LB-1 Licensing Assistant (2)

As further information is obtained, it will be distributed similarly. Appended to this document as Enclosures 3 and 4 are a general description of Sizewell and a listing of design modifications.

Original Signed by
H. R. Denton

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

Enclosures:
As stated

cc: E. Case
R. Minogue
J. Shea
T. Novak

*SEE PREVIOUS CONCURRENCE SHEET

OFFICE	NRR/TSB	NRR/DL/LB1	NRR/	TSB	NRR/PPAS/AD	NRR/DD	NRR/D
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ENCLOSURE 1

APPENDIX I

Major CEGB Changes to the SNUPPS Design

1. Use of a secondary containment (DST)

RSB/Orr 2. ECCS modifications (DSI with DST support)

   a. Two segregated steam-driven emergency charging pumps with separate water supply and not used for SI

   b. Upgraded isolation between RCS and RHR

   c. Four 100% HPIS pumps with larger capacity and lower shutoff head

   d. Larger (50%) SI accumulators

   e. Four 100% RHR pumps, two for LPSI, two for CSS with automatic switchover

SB Support /Huang 3. Two additional diverse 100% cooling water pumps for fan coolers to improve containment reliability (DST with DSI support)

RSB/Orr 4. Emergency boration system (DSI)

SB/Huang 5. Increased containment diameter and lower design pressure (DSI)

SB/Dunning 6. Back up reactor protection system (DSI)

SB/Lefave 7. Increased equipment redundancy (DSI with DST support)

   a. Four segregated 100% AFW pumps (two electric, two steam)

   b. Four 100% CCW and ESW pumps (also emergency dry cooling towers)

   c. Four segregated 100% diesels

8. Vessel and piping manufacture and inspection (DOE)

RAB/SKovholt 9. Layout and ALARA changes (DSI)

10. Redesigned control room (DHFS)

Open Issues in the NII Review

1. External hazards - fire, earthquake, and airplane crash (DOE with DST support)

PB/Power 2. Fuel clad ballooning (DSI)

SB Support/Liang 3. SG tube integrity and multiple SG tube failures (DOE with DSI support)

SB/Dunning 4. Integrated and secondary reactor protection system reliability (DSI)

B/Meyer 5. Accident code validation; ATWS and severe accident analyses (DSI)

<u>NII Confirmatory Issues</u>

1. Human factors analysis (DHFS)
2. QA (DOE)
3. Accident fuel performance code validation (DSI) — PB/Power
4. RPV and RCS failure - "incredibility" (DOE)
5. Component classification and design standards (DOE)
6. Extension of approval for non-remote sites (DSI) — EB/Dempsey
7. ALARA strategy, occupational exposure (DSI) — AB/Skopec

ENCLOSURE 2

SIZEWELL ISSUE ANALYSIS

Title: (Should uniquely identify the issue.)

Description: (Describe in 50-300 words the details of the design difference or open/confirmatory issue identified.)

SNUPPS Description: (Discuss in 50-300 words the SNUPPS design or licensing position on the issue.)

U.S. Acceptance Criteria: (Provide in 100-500 words the U.S. acceptance criteria and an analysis of how the SNUPPS plant met them. Don't just quote the SRP; explain how the design technically met them.)

Analysis: (Explain in 200-1,000 words the safety benefit the CEGB design change was intended to achieve or the risk underlying the NII concern.)

Areas for Further Exploration: (Identify further data required or questions to be asked during exchange.)

ENCLOSURE 3

CENTRAL ELECTRICITY GENERATING BOARD

GENERATION DEVELOPMENT AND CONSTRUCTION DIVISION

SIZEWELL 'B' PWR

The PWR Reference Design (April 1982)

A Comparison with SNUPPS and the Unadopted Design (April 1981)

1. Introduction

This paper compares the NNC April 1982 Reference Design with (i) the SNUPPS Design and with (ii) the Unadopted (April 1981) Design. The information is discussed in the text and also presented in tabular form (Table 1).

It should be noted that there are a few general items identified in the text (mainly associated with contamination control) which it would not be appropriate to present in the table (where itemised changes are specific). Apart from these the changes presented in the table are slightly more extensive than those identified in the text. In both cases, only the more important design differences are identified. Clearly, it is a matter of judgement as to the level of detail down to which it is appropriate to go.

The April 1982 Reference Design was evolved by a fresh start from the SNUPPS Design and not by making changes to the Unadopted (April 1981) Design. It is therefore not meaningful to describe the Reference Design on the basis of 'changes' from the Unadopted Design. Differences between these two designs are, however, not to the detriment of the Reference Design.

The April 1982 Reference Design is justified in nuclear safety terms in the Pre-Construction Safety Report. It is not the intention of the present paper to restate or summarise this justification. Rather, the paper simply indicates broad reasons for design provisions which differ from SNUPPS and comments, where appropriate, on the provisions in the Unadopted Design.

In providing the description it is convenient to classify the features of the various designs in six separate categories, which are discussed in Sections 2-7 below.

2. Safety features added which were also present in Unadopted Design

There are seven major safety features which have been added to the SNUPPS design to give the Sizewell 'B' design, all of which were also present in the April 1981 design. These are as follows:

(i) the four-pump High Head Safety Injection System (HHSIS)

(ii) the separation of the functions of the HHSIS and charging pump system

(iii) the larger accumulators

(iv) the forged-ring reactor pressure vessel

(v) the Emergency Boration System

(vi) the use of a 4-pump Essential Service Water System (rather than a 2-pump system)

(vii)* the provision of secondary containment

3. Safety features added which were not present in Unadopted Design

There are six major additional safety features added to the SNUPPS design to give the Sizewell 'B' design, which were not present in the April 1981 design. They therefore represent an improvement over the latter, and are as follows:

(i) the modifications to the upper section of the Reactor Vessel Cavity (allowing external in-service inspection of the nozzle region)

(ii) the Auxiliary Feedwater System with diversity of pump drives (two electrically driven and two steam driven pumps)

(iii) the computer based Reactor Protection System with a diverse secondary protection system

(iv) the provision of a steam driven emergency charging system (*second steam driven pump included after review - see Footnote).

Footnote

*The starred items of the lists in Sections 2-5 were included in the Reference Design as a result of the review which followed the issuing of the Reference Design Report and Pre-Construction Safety Report in draft form.

(v)* the provision of two additional pumps with associated pipework between the containment fan coolers and the reserve ultimate heat sink to provide increased diversity of the cooling supply to the containment fan coolers

(vi)* the extension of the high pressure piping on the residual heat removal (RHR) suction lines to the outside-containment isolation valves. This will reduce the probability of a loss of coolant accident occurring outside the containment.

4. Safety features added which differ in detail from the Unadopted Design

There are four major additional safety features added to the SNUPPS design to give the Sizewell 'B' design, which are different in detail from those in the April 1981 design, but which are provided as alternative ways of achieving the appropriate safety standards:-

(i) the arrangements for actuation of the recirculation phase during a LOCA (Loss of Coolant Accident)

(ii) the Emergency Electrical Supplies

(iii) the interchangeability of Residual Heat Removal and Containment Spray pumps

(iv) provision of additional isolating valves in the feed lines and space for additional isolating valves in the steam lines.

5. Design features added to reduce radiation exposure of operators

In addition to the safety-related changes the Reference Design incorporates a series of measures designed to reduce radiation exposure to operations and maintenance staff. These measures are either the same as, or equivalent to, measures in the Unadopted Design. They include:

(i) the adoption of a narrow vessel cavity Look-up Westinghouse Cavity

(ii) the use of a multi-stud tensioner and the integrated head package to reduce the time required to remove the vessel head during refuelling

(iii) the addition of some permanent sub-change rooms, barriers and wash facilities in the containment

(iv) improvements to the ventilation and air filtration systems for the containment

(v) an increased containment diameter, and

(vi)* improvements for personnel access and containment control including an extension building with change room facilities and additional sub-change rooms.

The SNUPPS design foresees a figure of around 400 man-rem/year as the likely operator dose. In the UK Reference Design these various design changes are included to meet a target of 240 man-rem/year. The introduction of these changes, while adding to the cost, can be justified bearing in mind the guidelines which require the industry to take all reasonably practicable steps to reduce operator doses to "as low as is reasonably practicable".

6. <u>Design changes to meet UK practices and Sizewell Site Requirements</u>

A number of changes from the SNUPPS design are required to meet UK practices and Sizewell site requirements. These same measures were included in the unadopted design. They include:

(i) the use of two turbine generators rather than one

(ii) the use of seawater cooling for the condensers rather than river water cooling or cooling towers

(iii) the use of 50Hz electrical machines including reactor coolant pumps

(iv) extension of systems served by the component cooling water system because the essential service water system uses seawater

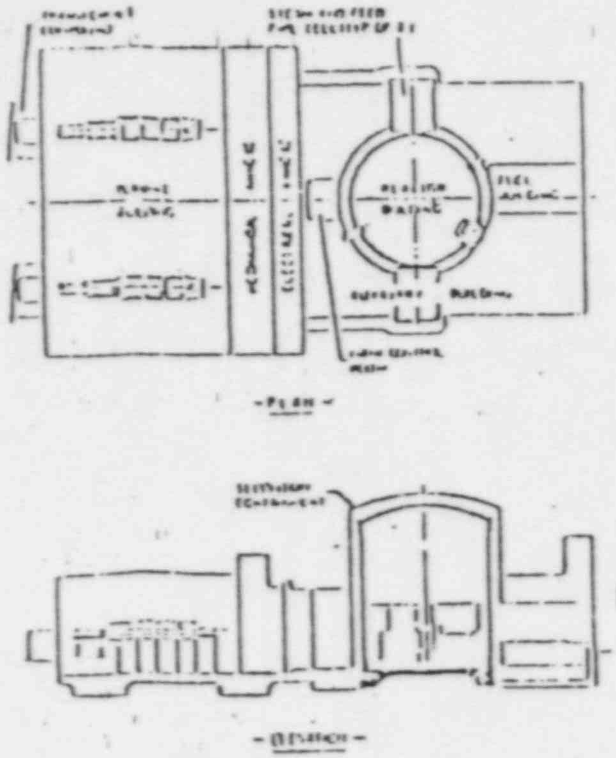
(v) the use of an air-cooled heat exchanger rather than a large cooling water pond for the reserve ultimate heat sink.

7. <u>Design of Auxiliary Building</u>

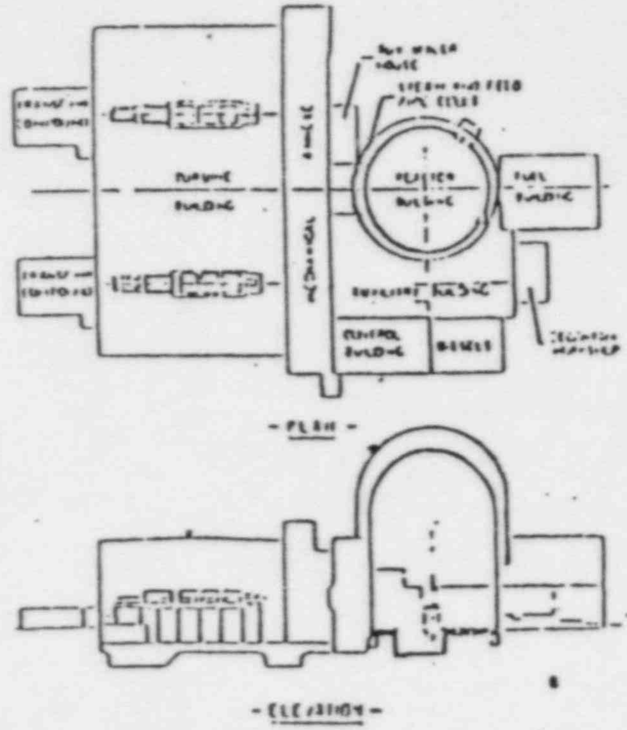
The reference design utilises the SNUPPS design of auxiliary building. The unadopted design had a "wrap around" auxiliary building which surrounded the containment building entirely. This concept failed to make the best use of the Bechtel experience in constructing the SNUPPS design in the United States. The SNUPPS layout relies less on physical barriers to separate essential mechanical and electrical systems

Nevertheless, the April 1982 Reference Design achieves the more extensive physical segregation appropriate to meet the CEGB Design Safety Guidelines, whilst still retaining the benefit of the SNUPPS arrangements. The unadopted design was also built on a common concrete raft shared between the containment and auxiliary buildings. This feature was considered unnecessary following the results from the latest site investigations at Sizewell and analysis of differential settlement under normal and seismic conditions.

Figure 1 shows the general layout of the Reference Design and of the Unadopted Design.



UNADOPTED DESIGN
APRIL 1981



REFERENCE DESIGN
APRIL 1982

FIGURE 1.

TABLE 1

Comparison of Designs

Feature	SNUPPS (Callaway)	April 1981 Unadopted Design	April 1982 Reference Design	Explanation of Change
Building layout	180' internal diameter containment with hemispherical head	157' internal diameter containment with torispherical head	150' internal diameter containment with hemispherical head	Diameter must be increased to accommodate larger pump motors, accumulators and features to reduce man-rem. Increase in 1981 was considered excessive. Hemispherical head was chosen because of ease of construction.
	Auxiliary building extending slightly more than 180° around containment building	Wrap around auxiliary building	Auxiliary building extending slightly more than 180° around containment building	Non wrap around auxiliary building is fundamental to the SNUPPS engineering and construction method.
	Containment and auxiliary building on separate foundation rafts	Containment and auxiliary building on common foundation raft	Containment and auxiliary building on separate foundation rafts	Design using a single raft was considered to be unnecessary following results of latest site investigation and analysis of differential settlement under normal and seismic conditions.
Nuclear steam supply system	Westinghouse 3425MW 4-loop plant	Same as SNUPPS	Same as SNUPPS	Fundamental aspect of all proposed designs.
	Reactor vessel fabricated from plate or forging	Reactor vessel fabricated from ring forgings	Same as 1981 Design	Avoids vertical welds in the part of the reactor vessel subjected to high neutron irradiation.
	'Standard' reactor vessel head design	Head design modified to accommodate multi stud tensioner	Same as 1981 Design	The multi-stud tensioner reduces the time required to remove and replace the vessel head and hence reduces man-rem dose.

TABLE 1 (Continued)

Feature	SNUPPS (Callaway)	April 1981 Unadopted Design	April 1982 Reference Design	Explanation of Change
	Narrow and wide reactor cavity designs available	Narrow reactor cavity design adopted	Same as 1981 Design	The narrow cavity reduces neutron streaming and induced activation and hence reduces man-rem dose.
	Standard cavity design	Standard cavity design	Modifications to upper section of reactor vessel cavity	Reference Design modification allows external in-service inspection of nozzle region of RPV.
	60Hz design for the reactor coolant pump (93A)	50Hz design for the reactor coolant pump (100D)	Same as 1981 Design	Requirement for UK design.
	Type 'F' steam generators	Same as SNUPPS	Same as 1981 Design	Design chosen to minimise secondary side corrosion.
Emergency core cooling system	Two high head safety injection pumps	Four high head safety injection pumps of increased capacity	Same as 1981 Design	Four pumps are provided to improve the reliability of safety injection. Increased pump capacity reduces peak clad temperatures and makes core uncovery less probable in the event of small LOCA.
	HHSI pumps taking suction from LHSI pump outlet in recirculation phase	HHSI pumps taking suction direct from the containment sump	Same as 1981 Design	Reference design approach simplifies arrangement of equipment and improves reliability.
	Charging pumps used as part of ECCS	Charging system isolated during ECCS operation except for RCP seal supplies	Same as 1981 Design	Charging system not required for emergency core cooling function because of increased capacity of high head pumps. The automatic action to isolate the charging system from the RCS (except for RCP seal supplies) in the event of a safety injection signal helps to limit the probability of inadvertantly pressurising the RCS to the safety valve lift pressure.

TABLE 1 (Continued)

Feature	SNUPPS (Callaway)	April 1981 Unadopted Design	April 1982 Reference Design	Explanation of [illegible]
	4 x 33% accumulators	4 x 50% accumulators	Same as 1981 Design	Increased capacity of accumulators leads to improved reliability [illegible] operation. Operati[illegible] accumulators is suff[illegible] SNUPPS requires 3.
	Initial injection from single tank located outside containment, (refuelling water storage tank used). Manual realligment of pumps at start of recirculation	Emergency water storage tank in base of containment - no requirement to realign pumps at start of recirculation	Initial injection from single tank outside containment. (Refuelling water storage tank used). Automatic realignment of pumps at start of recircu-lation	1981 design had [illegible] reliability because [illegible] was no requirement [illegible] realign the pumps [illegible] start of the recirc[illegible] phase. A similar degr[illegible] reliability is ac[illegible] the April 1982 design [illegible] automatic pump reali[illegible]
	Two low head safety injection/residual heat removal pumps with header system	Four low head safety injection/residual heat removal pumps feeding individual cold or hot legs	Four identical pumps, two normally aligned for LHSI/RHR duty, two aligned for contain-ment spray duty but provision made for manual realignment. Improvements in RHRs isolation from RCS.	The increased capa[illegible] the high head pump[illegible] that the low head [illegible] system can be sim[illegible] from the 1981 design [illegible] sacrificing relia[illegible]
	Two containment spray pumps	Four containment spray pumps		
	HP piping on RHR suction lines terminated within containment	HP piping on RHR suction lines terminated within containment	Extension of HP piping on RHR suction lines to outside-containment isolation valves	Reference Design mo[illegible] tion reduces probab[illegible] LOCA occurring outside containment.
Pressuriser system	'Standard' size for pressuriser relief tank	Relief tank volume increase by factor 2	Relief tank as in SNUPPS design	Analysis shows that the larger tank does not significantly increase range of incidents wh[illegible] be experienced without rupturing the tank bur[illegible] disc.

TABLE 1 (Continued)

Feature	SNUPPS (Callaway)	April 1981 Unadopted Design	April 1982 Reference Design	Explanation of Change
	'Standard' heater system in pressuriser	Back-up pressuriser heater system	Reserve heaters available	Analysis shows that sufficient time is available for the operator to connect up the reserve heaters if required.
Chemical and volume control system	2 centrifugal pumps and 1 positive displacement pump	3 centrifugal pumps and 1 positive displacement pump, plus back-up system of 2 centrifugal pumps	2 centrifugal pumps and 2 back-up positive displacement pumps	Analysis has shown that an adequate level of reliability can be achieved with the Reference Design configuration of pumps. Diversity of charging pump drives provides a greater security of the charging function against common mode failure.
Auxiliary feed-water system	2 x 100% electric motor powered pump + 1 x 100% steam driven pumps. All pumps delivering into the same feedwater nozzles	4 x 100% electric motor powered pumps + back-up system of 2 x 100% electric motor powered pumps. All feedwater supplies use the same nozzles in the steam generator	2 x 100% electric motor driven pumps delivering into separate nozzles on each steam generator. 2 x 100% steam turbine driven pumps delivering into main feed-water nozzles	Analysis has shown that an adequate level of reliability can be achieved with the Reference Design configuration of pumps. Diversity of auxiliary feed-water pump drives provides a greater security of feed-water supply against common mode failure.
Boration systems	Rapid boration system (within HHSI system) included	Rapid boration system deleted. Space provided for emergency boration system	Rapid boration system deleted. Emergency boration system included	Analysis has shown that there is no safety requirement for the rapid boration system provided in the SNUPPS design. It was provided with the intention of avoiding recriticality problems in a steam line break fault. The Sizewell B emergency boration system is provided for a different reason, namely to ensure that, following a limited range of frequent faults, a safe condition would exist even in the extremely unlikely event of some unidentified failure preventing insertion of the control rods.

TABLE 1 (Continued)

Feature	SNUPPS (Callaway)	April 1981 Unadopted Design	April 1982 Reference Design	Explanation of Change
Component cooling water system	2 train system - each train has 2 pumps and 1 single part heat exchanger	4 train systems - each train has 1 pump and 1 two part heat exchanger (giving up heat to the essential service water system)	2 train system - each train has 2 pumps and 1 two part heat exchanger	In the UK design, the component cooling water system (CCWS) carries some of the load carried by the essential service water system (ESWS) in SNUPPS. This is because the ESWS at Sizewell uses seawater as its coolant. This leads to a two-part heat exchanger in the CCWS.
Essential service water system	2 pump system	4 pump system	4 pump system	Reliability of the system improved by increasing the number of pumps.
Reserve ultimate heat sink	Use of large cooling water pond	Air-cooled heat exchangers in component cooling water system under consideration	1981 Design proposal confirmed	Air-cooled heat exchanger is more suitable for Sizewell site than a cooling pond. The functional requirements of Sizewell B reserve ultimate heat sink (RUHS) differ from those of the SNUPPS RUHS because the Sizewell B safety case does not require the RUHS to handle the post - LOCA heat rejection load
Cooling supplies to containment fan coolers	Via essential service water system	Via normal component cooling water system only	Two additional pumps provided between containment fan coolers and reserve ultimate heat sink	Reference Design modification provides increased diversity of cooling supplies to containment fan coolers.
Main steam and feed system	4 main steam lines each with 1 isolating valve (two actuators) and 1 power operated relief valve	4 main steam lines each with 2 isolating valves and 2 power operated relief valves	4 main steam lines each with 1 isolating valve (two actuators) and 1 power operated relief valve (space available for second isolating valve)	Analysis has shown that an adequate level of reliability can be achieved with a single isolating valve and a single PORV.

TABLE 1 (Continued)

Feature	SNUPPS (Callaway)	April 1981 Unadopted Design	April 1982 Reference Design	Explanation of Change
	One non-return valve in each feedwater line	Non-return valve and isolating valve in each feedwater line	Same as 1981 Design	The main feed isolating valves provide additional assurance that uncontrolled blowdown from more than one steam generator will not occur in the event of feed-water pipe rupture in the turbine building.
Turbine-generator	Single low speed turbine-generator	Twin high speed turbine-generator	Same as 1981 Design	Chosen to avoid use of a prototype turbine-generator in the first PWR plant in the UK.
Main heat rejection system	Forced draft wet cooling tower	Seawater cooling	Same as 1981 Design	Dictated by choice of site.
Electrical systems	60 Hz	50 Hz	50 Hz	UK grid frequency
	2 x 100% diesel generators feeding 2 separate distribution boards	4 x 100% diesel generators feeding 4 separate distribution boards + 2 x 100% back-up diesels supplying power to back-up systems	4 x 100% diesel generators feeding 4 separate distribution boards (Note: non-electric drives for auxiliary feed-water and charging pumps)	The diverse power supplies for certain vital equipment means that the required reliability for emergency electrical power can be provided with 4 diesel generators.
Reactor protection	Based on relays and solid state switches	Westinghouse Integrated Protection System - consideration being given to secondary system	Westinghouse IPS plus secondary protection system	The combination of the computer based Integrated Protection System and a secondary system gives a total protection system with the required reliability.
Refuelling equipment		Integrated head package under investigation	Use of integrated head package	Reduces time to remove and replace reactor head and hence reduces man-rem dose.

TABLE 1 (Continued)

Feature	SNUPPS (Callaway)	April 1981 Unadopted Design	April 1982 Reference Design	Explanation of Change
Fuel storage		Modification to restrict drop height of flask	Same as 1981 Design	UK practice
	Storage capacity of 1.6 reactor cores based on low density storage (7 years on basis of high density racking available as option)	Storage capacity of 7 reactor cores based on high density Storage	Same as 1981 Design	Creates opportunity for long-term consideration of UK policy on handling spent fuel.
Fuel Storage pond cooling system	2 x 100% cooling water pumps and 2 x 100% heat exchangers	4 x 100% cooling water pumps and 4 x 100% heat exchangers	4 x 50% cooling water pumps and 2 x 100% heat exchangers	Analysis of incidents involving loss of cooling of spent fuel pond indicates that the April 1982 design gives adequate reliability.
Secondary containment	No secondary containment provided over primary containment dome	Secondary containment over primary containment dome included	Secondary containment over primary containment dome included	To provide additional margins.

Table 2 Comparison of Sizewell B with SNUPPS

FEATURE	SNUPPS (CALLAWAY)	SIZEWELL B	COMMENT
Building layout	140' internal diameter containment with hemispherical head	150' internal diameter containment with hemispherical head	Diameter must be increased to accommodate larger pump motors, accumulators and features to reduce man-rem.
	Auxiliary building extending slightly more than 180° around containment building	Same as SNUPPS	Essential feature of the SNUPPS concept for access during construction
	Containment and auxiliary building on separate foundation rafts	Same as SNUPPS	Essential feature of SNUPPS layout permitting buildings to be founded at heights to suit plant layout
Reactor components	Westinghouse 3425 MW 4-loop plant	Same as SNUPPS	Fundamental to retaining benefit of proven design
	Reactor vessel fabricated from plate or forging	Reactor vessel fabricated from ring forgings	Avoids vertical welds in the part of the reactor vessel subjected to high neutron irradiation
	'Standard' reactor vessel head design	Head design modified to accommodate multi-stud tensioner	The multi-stud tensioner reduces the time required to remove and replace the vessel head and hence reduces man-rem dose
	Wide reactor cavity design	Narrow reactor cavity design adopted	The narrow cavity reduces neutron streaming and induced activation and hence reduces man-rem dose
	60 Hz design for the reactor coolant pump (93A)	50 Hz design for the reactor coolant pump (1000)	Requirement for UK design
	Type 'F' steam generators	Same as SNUPPS	Design chosen to improve tube integrity
Emergency core cooling system	Two high head safety injection pumps	Four high head safety injection pumps of increased capacity	Four pumps required to improve reliability and meet requirements of UK single failure criterion. Increased pump capacity reduces peak clad temperature during small breach LOCA.
	HHSI pumps taking suction from LHSI pump outlet in recirculation phase	HHSI pumps taking suction direct from the containment sump	Careful pump and pipework design used to prevent need for complex arrangement of equipment
	Charging pumps used as part of ECCS	Charging pumps switched off during ECCS operation	Charging pumps can be omitted from ECCS because of increased capacity of high head pumps. Deletion also reduces the chance of over-pressurisation of the primary circuit while at low temperature
	4 x 33% accumulators	4 x 50% accumulators	UK single failure criterion means that required operation must be dependent upon 2 rather than 3 accumulators working. Hence increased size
	Manual realignment of pumps from injection recirculation mode	Automatic realignment of pumps from injection recirculation mode	Improved reliability is achieved by automatic pump realignment
	[illegible]w head safety injection/ dual heat removal pumps with header system	Four identical pumps two normally aligned for LHSI/RHR duty, two aligned for containment spray duty	The increased capacity of the high head pumps means that the low head injection system can be

Table 2 continued

FEATURE	SNUPPS (CALLAWAY)	SIZEWELL B	COMMENT
Pressuriser system	'Standard' heater system in pressuriser	Reserve heaters available	Sufficient time is available for the operator to connect up the reserve heaters if required
Chemical and volume control system	2 centrifugal pumps and 1 positive displacement pump	2 centrifugal pumps + 2 back-up positive displacement diesel driven pumps	The required reliability is achieved by using a diverse power source for the back-up pumps
Auxiliary feed water system	2 x 100% electric motor powered pumps plus 2 x 100% steam driven pumps. All pumps delivering into the main feedwater nozzles	2 x 100% electric motor driven pumps delivering into separate nozzles on each steam generator. 2 x 100% steam turbine driven pumps delivering into main feedwater nozzles	Separate nozzles reduces risk of fatigue cracks due to low temperature feed water
Boration system	Rapid boration system (within HHSI system) included	Rapid boration system deleted. Emergency boration system added	Recent analysis shows that the rapid boration system to deal with recriticality during steam-line break accidents is not required. The emergency boration system provides an alternative reactor shutdown system in the event that the main system fails to operate
Component cooling water system	2 train system — each train has 2 pumps and 1 heat exchanger	2 train system — each train has 2 pumps and two-part heat exchanger	For Sizewell 'B' the component cooling water system carries some of the load carried by the essential water system in SNUPPS. This is because the EWS at Sizewell uses seawater as its coolant. This leads to a two-part heat exchanger in the CCWS
Essential service water system	2 pump system	4 pump system	Reliability of the system improved by increasing the number of pumps
Reserve ultimate heat sink	Use of large cooling water pond	Air-cooled heat exchangers in component cooling water system	Air-cooled heat exchanger is more suitable for Sizewell site than a cooling pond
Main feedwater	One non-return valve in each feedwater line	Non-return valve and isolating valve in each feedwater line	Engineering practice in the UK
Turbine-generator	Single low speed turbine-generator	Twin high speed turbine-generator	Chosen to avoid use of a prototype turbine-generator in the first PWR plant in the UK
Main heat rejection system	Forced draft wet cooling tower	Seawater cooling	Dictated by choice of site
Electrical system	60 Hz	50 Hz	UK practice
	2 x 100% diesel generators feeding 2 separate distribution boards	4 x 100% diesel generators feeding 4 separate distribution boards (Note: non-electric drives for auxiliary feedwater and charging pumps)	The diverse power supplies for certain vital equipment means that the required reliability for emergency electrical power can be provided with 4 diesel generators
Reactor protection	Single system based on relays and solid state switches	Primary system using micro-processors, and secondary system using 'Laddics'	Two systems required to meet UK safety requirements
Irradiated fuel handling	High li[illegible] ...ort vehicle [illegible] ...ng pond	Lock gates permit flask to enter at low level	UK practice to avoid risk of dropping flask
Fu[illegible]	Storage capacity of 1.6 reactor [illegible]	Storage capacity of [illegible] reactor cores [illegible]	[illegible]

Table 2 continued

FEATURE	SNUPPS (CALLAWAY)	SIZEWELL B	COMMENT
Fuel storage pond – cont	2 x 100% cooling water pumps and 2 x 100% heat exchangers	4 x 50% cooling water pumps and 2 x 100% heat exchangers	Analysis of incidents involving loss of cooling of spent fuel pond suggests that the Sizewell 'B' design gives adequate reliability
Personnel change rooms	US practice	Larger main change room and additional subchange rooms	CEGB practice for contamination control requires additional change rooms
Secondary containment	Enclosure building is not provided for Callaway but is an option with SNUPPS concept	Enclosure building provided	It has not been possible to provide conclusive evidence that leakage from prestressed containment structure is predominantly from the penetrated regions

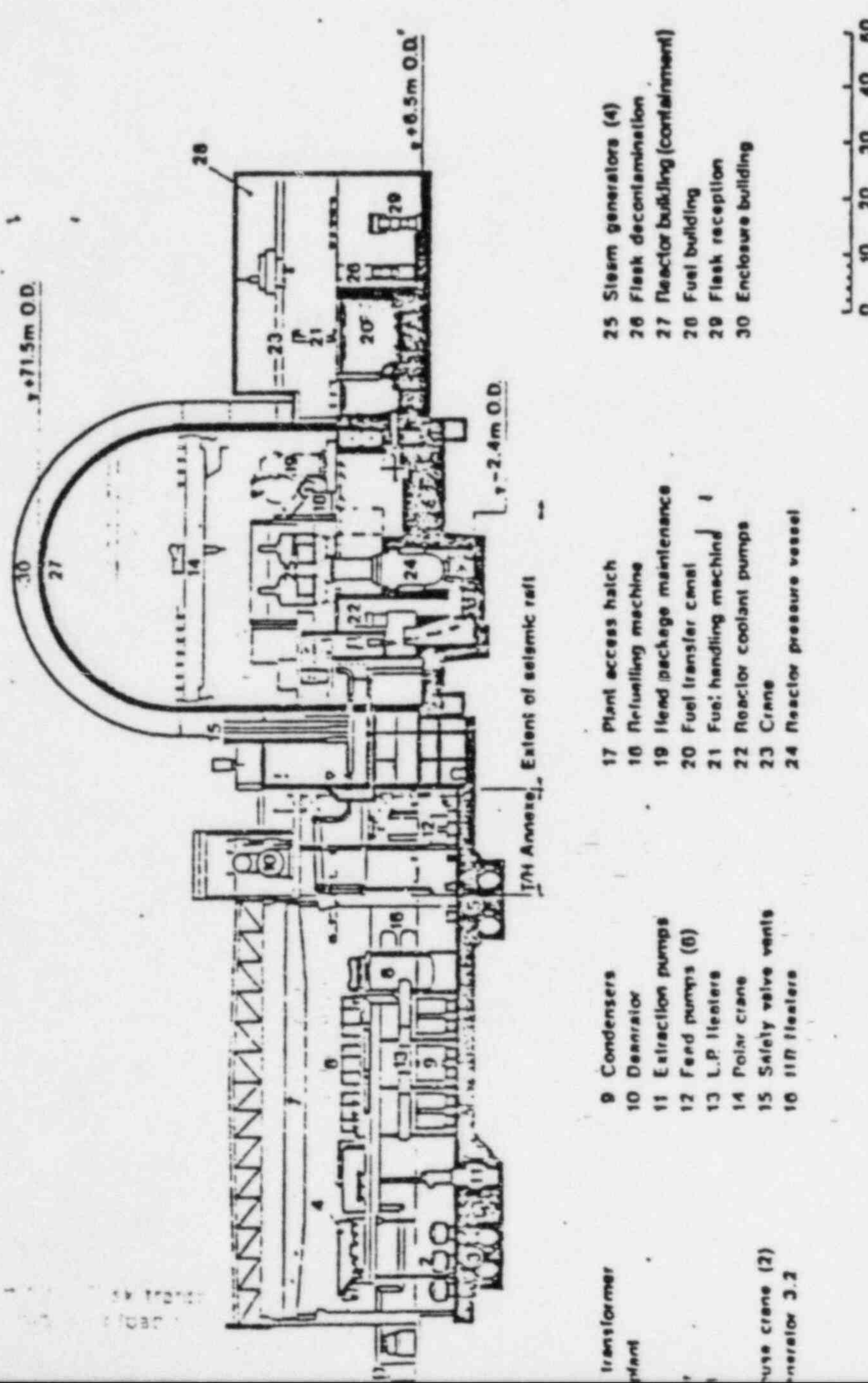
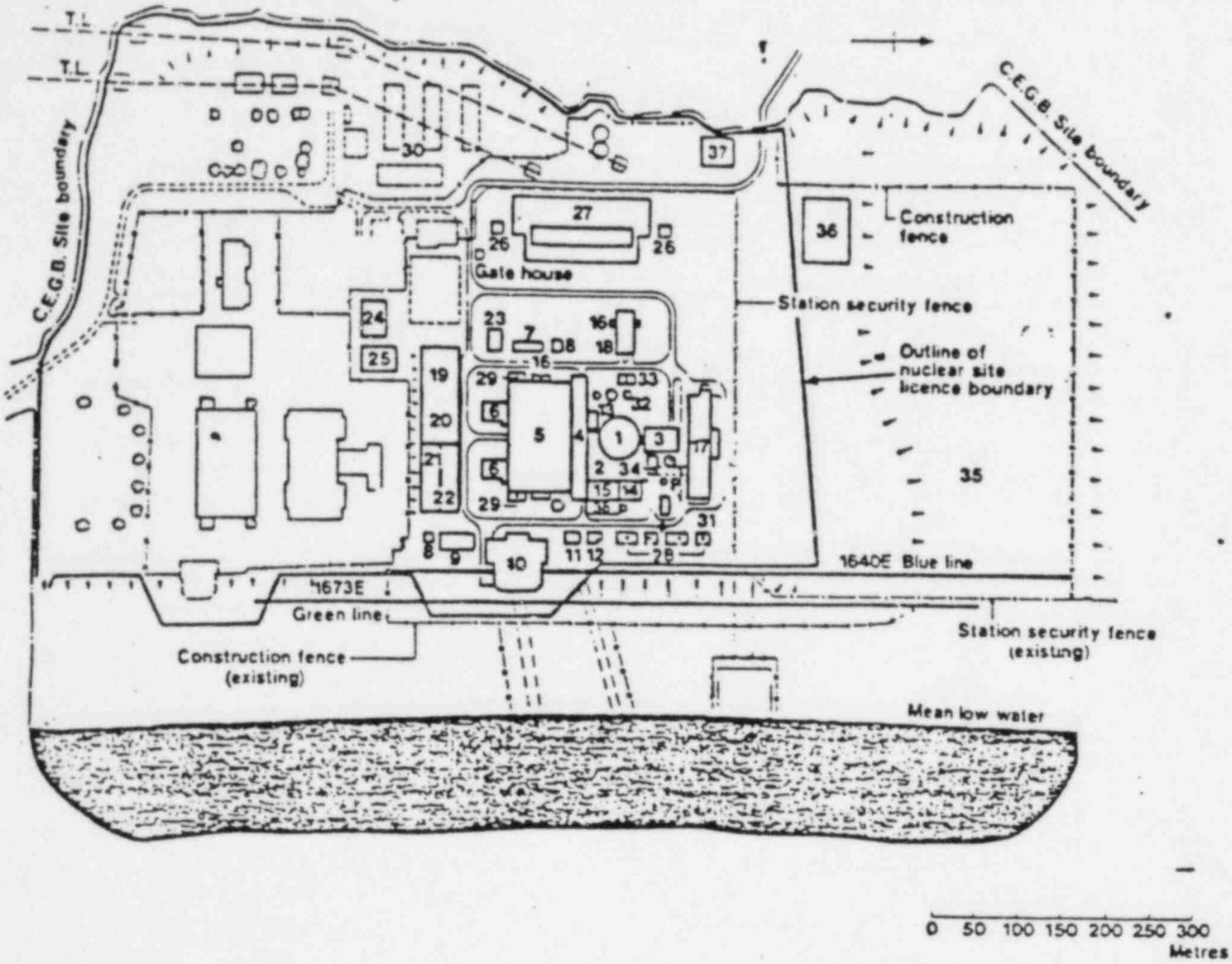


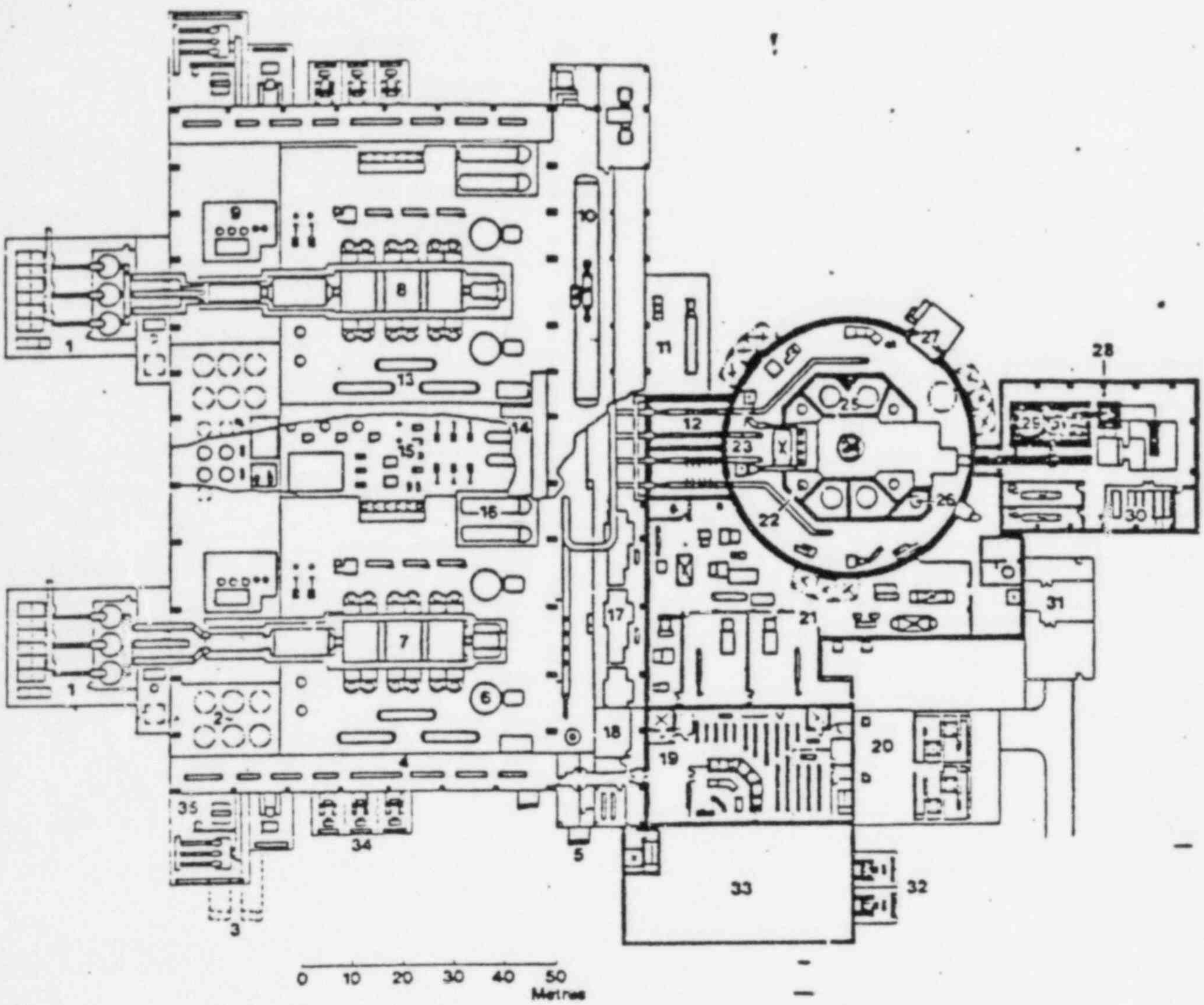
Fig 1 Sizewell B Power Station — section through station



Key

1 Reactor building (containment)
2 Auxiliary building
3 Fuel building
4 Turbine house annexe
5 Turbine house
6 Generator transformer
7 Water treatment plant building
8 Hydrogen release tank
9 Hypochlorite building
10 C.W. Pumphouse
11 Surge chambers
12 Nitrogen and CO_2 store
13 Auxiliary boiler house
14 Diesel house
15 Control building
16 Transformers
17 Radwaste buildings
18 Secondary diesel and control building
19 Workshop
20 Workshop stores
21 Welfare
22 Administration
23 Fire fighting pumphouse
24 Towns water reservoir No.1
25 Reservoir No.2
26 132kV substation
27 400kV substation
28 Reserve ultimate heat sink
29 Station transformers
30 Site hostel
31 Reactor make-up and refuelling water tanks
32 Demineralised and condensate water tanks
33 Fuel oil tanks
34 Decontam shop
35 Contractors' storage areas
36 Construction offices
37 Public information office
38 Main change building

Fig 2 Sizewell B Power Station – site plan



Key

1 Generator transformer
2 Polishing plant
3 C.W. Inlet
4 Switchgear
5 C.W. Outlet
6 Reheaters
7 Turbine generator 3.1
8 Turbine generator 3.2
9 Lubricating oil plant
10 Deaerator
11 Auxiliary boiler house
12 Steam mains
13 L.P. Heaters
14 Loading bay
15 Compressed air plant
16 H.P. Heaters
17 Feed pumps (6)
18 Technical support centre
19 Main control room
20 Diesel house
21 Auxiliary building
22 Reactor coolant pumps
23 Ventilating plant
24 Reactor pressure vessel
25 Steam generators (4)
26 Pressuriser
27 Plant access hatch
28 Fuel building
29 Fuel store
30 New fuel
31 Decontam shop
32 Essential transformers
33 Main change building
34 Transformers
35 Station transformers
36 Enclosure building

Fig 3 Sizewell B Power Station — plan of station

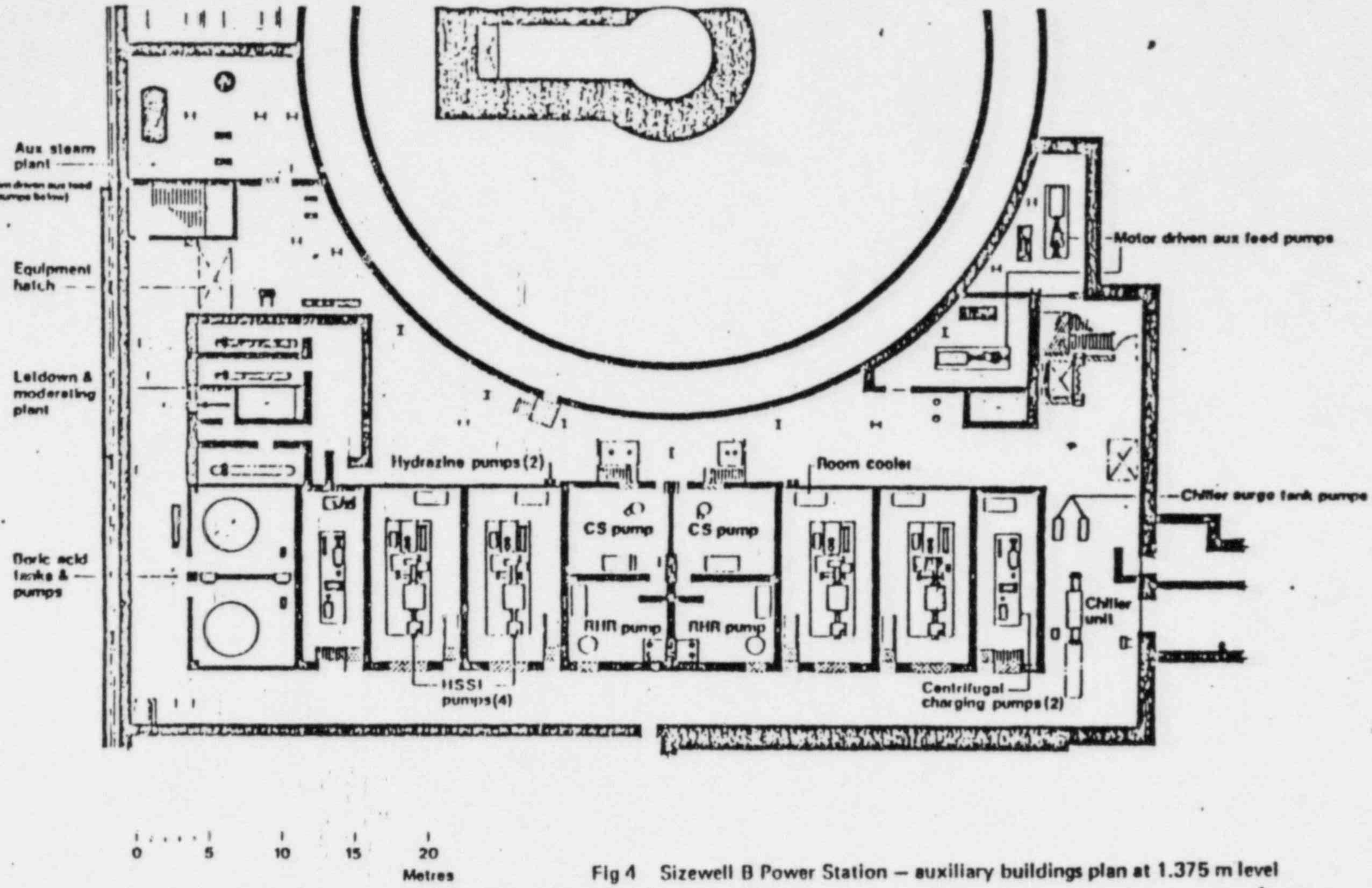


Fig 4 Sizewell B Power Station — auxiliary buildings plan at 1.375 m level

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ENCLOSURE 4

The pressurised water reactor design for Sizewell B

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SYNOPSIS The paper describes the PWR design for Sizewell 'B', with particular emphasis on the changes from the US reference plant introduced to meet the UK safety and other requirements.

1 INTRODUCTION

The Pressurised Water Reactor (PWR), developed in the United States and widely adopted elsewhere, is a mature reactor system for which there is a great deal of experience of both construction and operation. In order to take full advantage of this wealth of experience, it was decided that the PWR design for Sizewell B should replicate as far as practicable a reference plant being built in the USA. The reactor unit selected is a standard Westinghouse 4-loop design with a heat output of 3425 MW (thermal), equivalent to a net electrical output of approximately 1100 MW (e). Twelve similar units are already in operation and a further twenty are under construction. The power station incorporating this reactor unit, is the Standard Nuclear Unit Power Plant System (SNUPPS), which was designed by Bechtel for a group of US utilities and represents the latest nuclear plant design in the USA. Two SNUPPS stations are in an advanced stage of construction, one at Callaway, Missouri and the other at Wolf Creek, Kansas.

While the PWR design for Sizewell B follows closely that of Callaway, it has been necessary to make changes for the following reasons:

(i) Sizewell is on the sea coast, whereas Callaway is on a river - requiring changes to some auxiliary cooling systems to accommodate salt water and other site specific features.

(ii) The UK grid frequency is 50 Hz compared to 60 Hz in the USA - 50 Hz rotating equipment is generally larger than the 60 Hz equivalent.

(iii) The UK [illegible] metric units whereas Imperial units are used in the USA - this [illegible] standard sizes of piping and other

(iv) Sizewell B has to satisfy UK mechanical and electrical standards and engineering practices, particularly where UK manufactured equipment is to be used.

(v) Sizewell B design has to satisfy UK rather than US safety requirements and take account of changes in the US requirements for future plants, notably requirements arising from the accident at the Three Mile Island plant.

In addition to these obligatory requirements for Sizewell B, a lot of construction, operational and technological experience has been accumulated since the SNUPPS design was committed. Design changes for these reasons have only been made where the benefits are confidently expected to be large compared with the risks to cost and programme of introducing unproven features.

2 SAFETY REQUIREMENTS

Because of the importance rightly attached to the safety of nuclear power stations, it is perhaps appropriate to review briefly the impact which the different approach to safety in the UK and USA have had on the Sizewell B design. In the USA, the NRC licensing regulations are set out in great detail in document 10 CFR. In the UK, the NII place onus for proving that the design is safe on the operator and designer, who have to satisfy broad functional guidelines. A fundamental principle of these guidelines is that all reasonably practical steps shall be taken to reduce the exposure to radiation of the general public and the plant operators, both during normal operation and also as the result of accidents. One effect has been that more emphasis is placed in the UK on the provision of redundancy and diversity in those systems provided to mitigate the consequences of accidents. In particular, it is required that two independent and diverse groups of systems be [illegible]

of these groups of systems has to be highly reliable (the target is 10^{-3} to 10^{-4} failures per demand) and capable on its own of preventing an unacceptable release of radioactivity resulting from the initiating fault. A second consequence of the functional guidelines is reflected in the CEGB practices for the control of contamination and operator exposure during normal operation and maintenance of the plant, where greater provision of change rooms and ventilation systems is required than is normal in the USA.

3 THE REACTOR MAIN COMPONENTS

Heat is extracted from the fuel by water, pressurised at 2250 psig (about 158 atmospheres), which is pumped through the four closed loops, each of which contain a steam generator and a pump. The coolant circuit components are designed to withstand stresses resulting from seismic disturbances, cyclic flow induced loads and fault transients, as well as the normal operating conditions.

Fuel

The fuel is of standard Westinghouse design and consists of an array of fuel assemblies with slightly enriched uranium dioxide pellets contained within zirconium alloy tubes which are sealed and pressurised with helium. Each fuel assembly consists of 264 fuel rods mechanically located in a 17 x 17 square array (289 positions). The centre position in this assembly is reserved for the in-core instrumentation, while the remaining 24 positions are equipped with zircaloy guide thimbles available as core locations for rod cluster control assemblies, neutron source assemblies, or burnable poison rods. Reactivity is controlled by inserting or withdrawing the control assemblies, and by varying the concentration of boric acid in the coolant water.

Reactor Vessel Internal Structure

The reactor vessel internal structure which are of standard Westinghouse design, support the fuel assemblies and align the rod cluster control assembly guide tubes with the control rod drive. They also direct the flow of reactor coolant, provide gamma and neutron shielding, and provide guides for in-core instrumentation between the reactor vessel bottom head and fuel assemblies. They are fabricated of austenitic stainless steel. The internals consist of the upper core support structure which is removable for refuelling, and the lower core support structure which also has to be removed for internal vessel inspection.

Pressure Vessel

The pressure vessel is essentially the same design as that for SNUPPS, except that it will be fabricated from ring forgings. This avoids the longitudinal welds (which are more highly stressed than the circumferential welds) in the part of the vessel which experiences the highest neutron irradiation. The vessel is fabricated

vessel will be subject to exhaustive inspection during fabrication, before installation and during service. These measures address the concerns on pressure vessel integrity that have received so much attention. Similar standards of manufacture and inspection will be applied to the pressure retaining parts of the other components in the coolant circuit.

The pressure vessel is supported from pads located on four of the main coolant nozzles, which rest on the reinforced concrete structure surrounding the vessel. A design with a restricted gap between the vessel and concrete shield, known as the 'narrow cavity' design was chosen, rather than the 'wide cavity' of SNUPPS because it reduces the irradiation exposure of operators during refuelling.

Steam Generator

The steam generators are of shell and tube construction with steam separators at the top. The steam generator consists of three sections; a hemispherical bottom head carrying the primary coolant inlet and outlet nozzles, an evaporator section enclosing the U-tube bundle, and an upper section enclosing the steam separators. Access openings permit inspection and plugging of the tubes and water lancing of the upper surface of the tube plate. The steam generators are the latest Westinghouse 'F' type which incorporate features to avoid the tube denting and crevice and stress corrosion which have occurred with earlier designs. These features include:

> stainless steel tube support plates with Quatrefoil holes - avoids the problem of tube/plate erosion.
>
> Full depth hydraulic expansion of tubes to tube sheet, avoids crevice corrosion.
>
> Modified baffling to improve circulation ratio - avoids sludge deposition and consequent tube dry-out and corrosion.
>
> Thermally treated Inconel-600 tube material - increases the resistance to stress corrosion cracking.

The steam generator is supported by four articulated columns. Upper and lower lateral restraints are provided to withstand seismic loads, and the loads which would occur in the event of a pipe rupture. The reactor coolant flows into the channel head at the bottom of the steam generator, through Inconel U-tubes and back out of the channel head to return to the reactor vessel. Feedwater enters near the top of the steam generator, where it mixes with the re-circulation flow from the centrifugal steam separators and passes down the annulus between the tube bundle and the shell. It then rises between the U-tubes to the steam separators from where the separated steam is piped to the turbine generators.

Reactor Coolant Pumps

water lubricated bearing in the pump casing.

The pumps are driven by 6 MW constant speed, air cooled, vertical squirrel cage induction motors with oil lubricated thrust and radial bearings. Pumps and motors are of established designs which have been tested at overspeeds of up to 125 per cent of nominal speed. The pumps are supported on articulated columns and restrained laterally by seismic dampers and pipe whip restraints.

Pressuriser

The reactor coolant pressure is controlled by a single pressuriser connected to the hot leg of one of the loops. The pressuriser is a vertical, cylindrical pressure vessel with hemispherical top and bottom closures. It is fabricated in carbon steel with austenitic stainless steel cladding on all surfaces exposed to the reactor coolant. During operation a water level is maintained in the pressuriser by adding or removing water from the coolant circuit to compensate for the expansion and contraction of the coolant during operation.

To reduce the coolant pressure cool water is sprayed into the pressuriser. This condenses some of the steam and reduces the water temperature. Electrical immersion heaters in the pressuriser raise the saturation temperature and pressure to increase the coolant circuit pressure. Increases in pressure beyond the capability of the spray system cause power operated relief valves to open to relieve the pressure by discharging fluid into the pressuriser relief tank in the containment building. At pressure settings below the design limits of the system, additional spring-loaded safety valves automatically open to prevent overpressurising the coolant circuit.

Containment

The reactor and coolant loops are housed within a cylindrical steel-lined prestressed concrete containment building with a hemispherical roof, see Figure 1. It is designed to contain releases from accidents in which coolant escapes from the primary system. A spray system is provided to condense steam in the event of such an accident and so reduce pressure, and to wash out iodine and particulate fission products. Fan coolers are provided to control the temperature within the containment during normal operation, and they also serve to reduce temperature and pressure within the containment following a loss of coolant accident. Massive reinforced concrete internal structures support the primary coolant plant within the containment. These structures are designed to withstand the loads from plant restraints in the event of an earthquake or a rupture of a high pressure pipe. The containment is partially enclosed by the auxiliary building which houses the reactor coolant auxiliary systems. This building encloses the penetrated region of the containment building, and provides a "secondary" [illegible] any leakage which might occ[illegible] containment building through these penetrations, and [illegible]

3 REACTOR AUXILIARY SYSTEMS (Normally Operating)

The Chemical and Volume Control System (CVCS)

The chemical and volume control system (CVCS) has the following functions:

Regulation of the boric acid concentration in the reactor coolant to compensate for reactivity changes during start-up and shutdown, and due to fuel burn-up.

Regulation of the reactor coolant inventory to maintain pressuriser level within the allowable range.

Treatment of the reactor coolant by continuous removal of corrosion and fission products and maintenance of the correct hydrogen concentration.

A small quantity of reactor coolant is continuously discharged through regenerative and non-regenerative heat exchangers and pressure reducing orifices. Purification is affected by a system of demineralisers and filters. Regulation of boron is achieved by the boron thermal regenerative system (BTRS), which adds or removes boron according to the temperature of the ion exchange resins. Two centrifugal charging pumps, one is sufficient for the duty, return the CVCS flow to the reactor coolant circuit. Part of this flow is directed to the reactor coolant pump seals.

The Component Cooling Water System (CCWS) and Essential Sea Water System (ESWS)

The component cooling water system is provided to cool the main reactor components and auxiliary systems. The main heat loads are:

The reactor coolant pump thermal barriers

The chemical and volume control system heat exchangers

The residual heat removal heat exchangers

The containment fan coolers

The spent fuel pond cooling system.

The system is arranged in two halves, each equipped with two pumps, a main and subsidiary heat exchanger and a surge tank. The system is a closed loop and uses demineralised water, dosed with a corrosion inhibitor, and it normally rejects heat to the essential water cooling system. It can also reject heat to the reserve ultimate heat sink which is a forced draught water to air heat exchanger.

4 SHUTDOWN COOLING SYSTEM

There are several systems designed to safeguard the reactor when it is shut down normally, or following a fault or an accident:

Auxiliary Feed System

or shutdown heat, which amounts to some 100 MW(th) five minutes after shutdown. Normally this heat continues to be removed through the steam generators, with steam bypassed direct to the turbine condensers. When the condenser or the main feed system is unavailable, the steam generators are cooled by either of the two auxiliary feed systems. One of the auxiliary feed systems has two pumps driven by electric motors, and the other has two pumps driven by small steam turbines supplied from the steam generators. These pumps are supplied from two separate condensate water storage tanks. Should neither main condenser be available, steam is discharged to atmosphere through relief valves.

Residual Heat Removal System (RHRS)

When the reactor coolant temperature and pressure have fallen sufficiently, the shutdown reactor can be cooled by the residual heat removal system (RHRS). This has two parallel loops, each with a heat exchanger and two pumps; one loop with one pump is sufficient for the duty. The system is connected to the reactor coolant circuit through valves which are normally closed. It enables the reactor coolant to be reduced to atmospheric pressure, and if desired the circuit opened for refuelling during which it continues to remove the reactor shutdown heat. The RHR system also forms part of the Emergency Core Cooling System, operating in a low pressure injection or re-circulating mode (see below). The system is also designed to permit the pumps to be aligned to supply the containment spray system.

Emergency Core Cooling System (ECCS)

In the unlikely event of a loss of coolant accident (LOCA), it is necessary to inject water into the coolant circuit to prevent the core being uncovered and the fuel overheating. This is done by the Emergency Core Cooling System (ECCS). This system is designed to provide core cooling for accidents up to and including the hypothetical instantaneous double-ended rupture of a reactor coolant pipe.

The ECCS is automatically actuated by signals indicating:

low pressuriser pressure

High pressure in the containment building

Low steam line pressure.

The system contains four high pressure injection pumps, provided to deal with small LOCA in which the coolant pressure remains high for a considerable time. In the case of a large LOCA (e.g. major pipe rupture) the coolant pressure falls very rapidly, and a rapid injection of water is required to replace that lost through the breach. This is achieved by four accumulators, storage vessels containing borated water and pressurised by nitrogen gas, one of which is connected to each coolant loop. The accumulators have been sized so that two will provide the required duty. When the accumulators have emptied, water continues to be injected by low head injection [illegible] containing borated water and when this is emptied they re-circulate water from the sumps in the containment building, rejecting heat to the RHRS heat exchangers. Alternatively, the required flow of water can be provided by three of the four high head injection pumps.

5 REFUELLING

Approximately one third of the fuel in the core is replaced each year. The operation is carried out with the reactor shut-down, and cooled to low temperature and atmospheric pressure. A multi-stud tensioner and integrated head package is provided to reduce the time required for removing the vessel head and internals prior to refuelling, and hence to reduce the irradiation exposure of the operators. The cavity above the reactor is flooded to form a pool through which the reactor vessel head and upper internal structure are removed, and the fuel lifted from the vessel and transferred from the primary containment building to a storage pond in the adjacent fuel building. After a period to allow much of the radioactivity to decay, the fuel is put into a flask for transport to the reprocessing plant at Sellafield. The fuel storage pond will accommodate up to 18 years' output of irradiated fuel giving a high degree of independence of off-site storage and reprocessing facilities.

6 CONTROL AND PROTECTION SYSTEMS

The control and protection systems serve two general purposes:

to regulate the reactor heat output to match the turbine-generator load

to monitor plant operating conditions, and in the event of potentially unsafe conditions, automatically to trip the reactor and actuate the necessary safeguards system.

The reactor power is regulated by actuating the control rod drive mechanisms which are mounted on the reactor vessel head. The drive mechanism is a standard Westinghouse electro-mechanical jacking device, which moves the cluster up or down in a series of small steps. The drive mechanism housing forms part of the coolant circuit boundary, so that no seals are required on the control rod drive shafts.

Most plant instruments work through continuous readings on one of three parameters; temperature, pressure or neutron flux. Automatic control systems are provided to simplify the complex activities entailed in start-up and shutdown of the plant and in changing output. The main control room which is adjacent to the reactor auxiliary building, will be a UK design employing the latest ergonomic principles and taking account of the lessons of the Three Mile Island accident, and provided with ventilation arrangements which prevent ingress of contaminated air.

The reactor protection system represents a complete departure from SNUPPS. Two systems of

system is based on micropressor technology, and the secondary system also employs solid state elements, namely the 'Laddic' elements developed for the UK gas cooled reactors. The normal method of tripping the reactor is by interrupting the electrical supplies to the control rod mechanisms. This allows the control rod assemblies to drop into the core. An emergency boration system provides a diverse method of shut-down in the very remote possibility of sufficient control rods failing to enter the core. Automatic reactor protection and safeguards systems actuation and control are provided so that the safety of the public does not depend on actions by the operator for half-an-hour. This gives the operator time to determine the nature of the fault and appraise the plant state from the data display systems before taking action.

7 TURBINE-GENERATOR PLANT

The turbine generators are arranged side by side in the turbine house with a central maintenance and loading bay between them. They are 3000 rpm machines with a normal full load gross electrical output of 600 MW. Each turbine has a double flow high pressure cylinder and three double flow low pressure cylinders. The turbine generators and the condensing sea-water cooling, feed heating and feed pump systems are all based on well established practice. Four main steam pipes, provided with relief valves and quick closing isolating valves to deal with faults take steam from the steam generators to the turbines. Titanium condenser tubes with double tube plates are used to reduce the risk of sea water ingress. To protect the steam generators from corrosion, the condensate is treated in an ion exchange demineraliser, which also precludes contamination from sea water.

8 ELECTRICAL SYSTEM

The turbine generators feed the 440 kV grid line via two generator transformers. They also supply the station auxiliaries through two unit transformers feeding the internal distribution system at 11 kV. Breakers enable the generators to be coupled or uncoupled from the grid or station internal system. An alternative source of power for the station auxiliaries is provided by two station transformers which are connected to the 132 kV grid line. The station main distribution voltages are 11 kV, 3.3 kV and 415 kV. In the case of loss of electrical supplies from the grid, four diesel generators are provided, any one of which is adequate to supply essential loads in most circumstances.

9 STATION LAYOUT

The station layout, see Figure 2, has been designed to be adaptable to a wide range of site conditions. The power block arrangement provides good access to the building for construction and operation, and minimises the lengths of interconnecting service pipework and electrical power and control cables. The following buildings comprise the power block, see Figure 3:

Reactor containment building
Auxiliary building
Diesel building
Auxiliary boiler house
Turbine house including mechanical annexe

These buildings are provided with ventilation and filtration systems to limit the release of radioactivity to the environment in the event of an accident. The arrangement of the buildings is chosen to provide direct access to the reactor containment during construction, thus giving good access for the installation of major plant.

Important buildings which are separate from the main block are the cooling water pumphouse, the radioactive waste processing and storage buildings, the secondary diesel house and emergency control building, together with workshops, offices, storage tanks and towns water reservoirs. A service tunnel for pipe, cable and personnel access joins the radioactive waste processing building to the auxiliary building.

The secondary diesel and emergency control building, and its associated essential auxiliary transformers and fuel tanks, are located on the opposite side of the reactor containment building from the main control room and diesel house. This is to avoid the possibility of losing both primary and secondary control systems or power supplies as a result of a major fire, or missiles resulting from the disruptive failure of rotating plant. For the same reason, the station, unit and auxiliary transformers are separated in groups on either side of the turbine house. Similarly, water storage tanks are grouped on opposite sides of the main buildings and remote from towns water reservoirs. Cable routes from the main control room and diesel house to essential reactor equipment are segregated from the cable routes associated with the secondary diesel and emergency control building.

Plant layout within buildings is the most important means of protecting safety related equipment from fires. The auxiliary building, see Figure 4, which houses the auxiliary feed system, the residual heat removal system, the reactor charging pumps and the emergency core cooling system is divided into two broadly symmetrical areas, each area containing sufficient plant to perform the required safety function. The two diesel generators in the adjacent diesel house are similarly segregated, with each supplying the plant in one half of the auxiliary building through segregated cable routes. Control cables are also segregated through cable spreading rooms above and below the main control room. Within the containment, cables are segregated mainly by distance.

Personnel access to potentially contaminated areas is via the main change rooms located in the control building. A number of sub-change rooms are located in the auxiliary and fuel buildings to confine the spread of contamination, particularly during maintenance. Ventilation flows are controlled to ensure that the direction of flow is always from the less to the more highly contaminated zones, from where it is discharged through filters to the ventilation stack.

10 CONCLUSIONS

The PWR design for Sizewell B is based on the standard Westinghouse four loop reactor of which thirty-two units are in operation or under construction. The station design is based on Bechtel's SNUPPS designs now in an advanced stage of construction at Callaway in Missouri and Wolf Creek in Kansas. Design changes have been made where necessary to meet UK safety and other essential requirements. The design also takes account of technological and safety developments world-wide, including the lessons from the accident at the Three Mile Island plant in the USA. A summary of the changes is set out in Table 2, from which it can be deduced that they have minimum impact on the reactor itself, and that the general arrangement of auxiliary plant follows closely that of SNUPPS. Thus the benefits of replicating existing plant, in terms of confidence of meeting construction programme and cost targets have been retained.

Table 1 Plant data

Station thermal power of reactor	3411 MW
Station gross electrical output	1182 MW
Station internal power consumption	72 MW
Station net electrical output	1110 MW
Fuel assembly array	17 x 17
Number of fuel rods	264
Number of guide tubes:	
for absorber	24
for in-core instrumentation	1
Mass of UO_2 in fuel assembly	523.4 kg
Fuel rod: length	3851 mm
outside diameter	9.5 mm
cladding thickness	0.57 mm
Number of fuel assemblies	193
Number of control assemblies	53
Linear heat rating: average	17.8 kW/m
maximum	41.3 kW/m
Coolant pressure at vessel inlet	158.3 bar a
Coolant pressure at vessel outlet	155.1 bar a
Coolant temperature: vessel inlet	293.4° C
vessel outlet	324.9° C
Coolant flowrate	18740 kg/s
Reactor vessel overall height with the head	13.55 m
without the head	10.08 m
Reactor vessel inside diameter	4.39 m
Total vessel thickness (opposite the core)	215 mm
Minimum stainless cladding thickness	3 mm
Reactor vessel weight (including head)	385 t
Steam generator overall height	20.63 m
Steam generator upper part diameter	4.468 m
Steam generator lower part diameter	3.434 m
Steam generator U-tubes: number	5626
outside diameter	22.22 mm
thickness	1.02 mm
Steam generator (weight) empty	306 t
Reactor coolant characteristics:	
feedwater temperature	227°C
steam temperature	285°C
steam pressure	69 bar a
steam flow rate	477 kg/s