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Design Strategies and Evaluation for Sharing Systems at Multi-Unit Plants Phase I

August 2007

Michael D. Muhlheim
Richard T. Wood

UT-BATTELLE

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Nuclear Science and Technology Division

DESIGN STRATEGIES AND EVALUATION FOR SHARING SYSTEMS AT MULTI-UNIT PLANTS, PHASE I

Michael D. Muhlheim
Richard T. Wood

August 2007

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Abbreviated terms

ac	Alternating current
BFN	Browns Ferry Nuclear
BOP	Balance of plant
BWR	Boiling-water reactor
CDF	Core damage frequency
CFR	Code of Federal Regulations
COL	Combined operating license
DBA	Design basis accident
dc	Direct current
ESF	Engineered safety feature
ESW	Emergency service water
GL	Generic Letter
HVAC	Heating, ventilation, and air conditioning
IPE	Individual plant examination
IRIS	International Reactor Innovative and Secure
LER	Licensee event report
LWR	Light-water reactor
MWe	Megawatt electric
NRC	Nuclear Regulatory Commission
O&M	Operations and maintenance
PBMR	Pebble Bed Modular Reactor
PRA	Probabilistic risk assessment
PWR	Pressurized-water reactor
SSC	Structures, systems, and components
SAFR	Sodium advanced fast reactor
T/G	Turbine generator
TS	Technical specification
TVA	Tennessee Valley Authority

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ABSTRACT

The sharing of systems between units at a nuclear plant site should prove to be significantly beneficial both economically and operationally. The sharing of systems between units means that only one system needs to be built rather than two. This translates into a reduction of overall construction time and in the capital outlay for equipment, materials, and structures. Regardless of the material benefits, safety cannot be compromised—that is, the sharing of systems cannot significantly impair the ability of the systems to perform their safety function(s). Thus, an important objective of sharing systems is to reduce cost while maintaining safety. More specifically however, the objective of this I-NERI project is to evaluate the system implications of multiunit nuclear power plants by performing four tasks over a three year period:

1. Identifying opportunities for sharing
1. Developing resource sharing strategies
2. Determining impact of common systems/resources
3. Providing a methodology to identify and evaluate sharing options

The findings of this investigation, while focused on the International Reactor Innovative and Secure (IRIS) concept as a case study, are extendable other multi-modular reactor concepts. This report identifies those plant systems that can be considered for sharing between units. In addition, it provides initial identification of key considerations in the development of a decision support methodology for defining a cost effective multi-modular implementation approach that preserves the desired safety characteristics of advanced plants.

The preferred IRIS plant arrangement offered for the early site permit envelope is two twin units with a total output of 1340 MWe. According to Westinghouse, “The twin arrangement is aimed at maximizing shared components between the two modules that make up one twin unit, yet it has the ability to initiate operation of a completed twin unit while construction of subsequent twin(s) proceeds in a ‘slide-along’ manner. . . This arrangement and construction sequencing is aimed at minimizing the construction time of a unit and at providing the utility with generating capability as soon as possible.”

There are almost 100 systems that make up a nuclear power plant. The economies of sharing structures and systems between units can be significant. However, the proper selection of systems and structures to be shared cannot be made based on economics alone. Safety, operability, and licenseability are also factors. Yet, of the 100 systems, about three-fourths of these systems are not evaluated in the probabilistic risk assessment (PRA). Therefore, selecting systems for sharing based on safety alone would severely limit the benefits and savings of sharing systems.

Once the selection of possible systems available for sharing is expanded to all systems, there are numerous metrics to consider, some of which may conflict. The design needs to consider all systems located outside containment as potential candidates for sharing but must also allow for one unit to operate while another is being constructed.

Conclusions from the first phase of the assessment for sharing systems are:

- Regulations allow sharing but the safety impact must be assessed in detail;
- Decision metrics are necessary to evaluate cost, safety, reliability, and performance;
- Primary systems are not candidates for sharing;
- The number of systems that are shared and the type of sharing directly relates to the complexity of the safety, risk, and accident assessments; and
- “Slide along” construction is a viable and proven concept.

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1. INTRODUCTION

The sharing of systems between units at a nuclear plant site should prove to be significantly beneficial both economically and operationally. Consider that the sharing of systems between units means that only one system needs to be built rather than two. This translates into reduced overall construction time and a reduction in the capital outlay for equipment, materials, and structures. Regardless of the material benefits, safety cannot be compromised—that is, the sharing of systems cannot significantly impair their ability to perform their safety function(s). Thus, a simplistic objective of sharing systems is to reduce cost while maintaining safety. More specifically however, the objective of this I-NERI is to evaluate the system implications of multiunit nuclear power plants by performing four tasks over a three year period:

1. Identifying opportunities for sharing
   - Identify potential systems that could be available for sharing (BOP, safety-related, auxiliary, I&C, electrical, and structures)

2. Developing resource sharing strategies
   - More completely define the variety of options for taking advantage of multiple units for reducing cost, increasing efficiency, and enhancing reliability

3. Determining impact of common systems/resources
   - Assess economic impact
   - Identify technical challenges
   - Identify and evaluate system effects on safety, reliability, and performance

4. Providing a methodology to identify and evaluate sharing options to support design decisions
   - Develop metrics to evaluate cost, safety, reliability, and performance
   - Identify missed opportunities for sharing and detrimental impact on operations because of sharing

The opportunities for sharing systems and the methodology developed to measure the value of implanting these opportunities will be applied to the International Reactor Innovative and Secure (IRIS) plant.

The preferred IRIS plant arrangement offered for the early site permit envelope is two twin units with a total output of 1340 MWe (Fig. 1). According to Westinghouse,[1]

> The twin arrangement is aimed at maximizing shared components between the two modules that make up one twin unit, yet it has the ability to initiate operation of a completed twin unit while construction of subsequent twin(s) proceeds in a “slide-along” manner. This means that multiple units are started up in sequence as construction, preoperational testing, fuel load, and startup testing are all completed for a unit. The first completed unit will be operated while construction of the subsequent unit(s) is still in progress, by establishing a temporary exclusion zone between the operating unit(s) and the unit(s) under construction. This arrangement and construction sequencing is aimed at minimizing the construction time of a unit and at providing the utility with generating capability as soon as possible.

Each twin unit is completely independent from the subsequent twin(s) and each reactor within a twin has its own turbine generator (T/G), condenser, and feed and steam systems, contained in a single T/G building with their own nonsafety service water and main circulating water mechanical draft cooling towers. Within a twin unit, however, many systems, functions, and physical facilities are shared, including control room, fuel handling area with refueling machine and spent fuel pit and cask loading facility, radwaste treatment, support systems, and switchyard. Within the twin unit, separate safety-grade power supplies, protection cabinets and switchgear, and electrical systems are maintained.

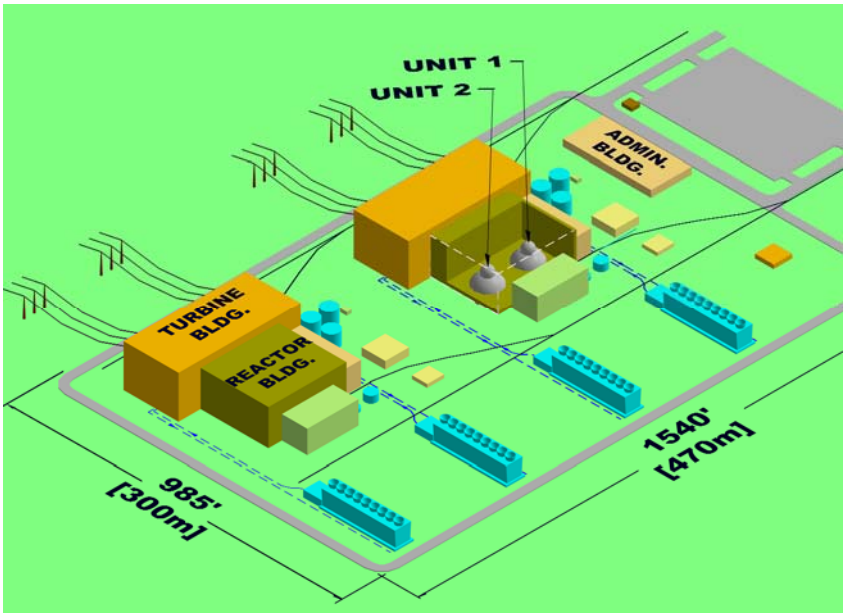

Fig. 1 A two twin-unit plant layout arrangement for IRIS (1340 MWe per twin-unit station).[1]

2. FACTORS THAT INFLUENCE PLANT ARRANGEMENT

There are four factors that influence the sharing of systems at multiunit plants:

1. economics,
2. safety,
3. operability, and
4. licensing considerations.

Each of the factors will be evaluated in the following subsections.

2.1 Economics

The genesis for designing a twin-unit station is not to maximize the use of shared equipment to lower the core damage frequency (CDF), but to reduce the cost of construction and equipment while maintaining the characteristics of a safe and reliable plant. For example, cross-ties between fully redundant systems may lower the CDF but do nothing toward reducing costs. Consider that Cook Units 1 and 2 (Westinghouse) share the essential service water, nonessential service water, compressed air, and the switchyard. Cross-ties exist between the component cooling water and auxiliary feedwater systems at each unit. At Cook, there is not much direct sharing of systems in that one combined system serves both units; Cook relies on each unit having full capacity, independent systems but those systems can be cross-tied between units to serve as backups. This type arrangement can help reliability and safety but actually adds to the cost.

2.1.1 Multi-unit vs. modular

Modular construction consists of assembling self-aligning modules that were pre-fabricated offsite; this is not the same thing as sharing (Figs. 2 and 3). Modular construction however, does not preclude sharing.

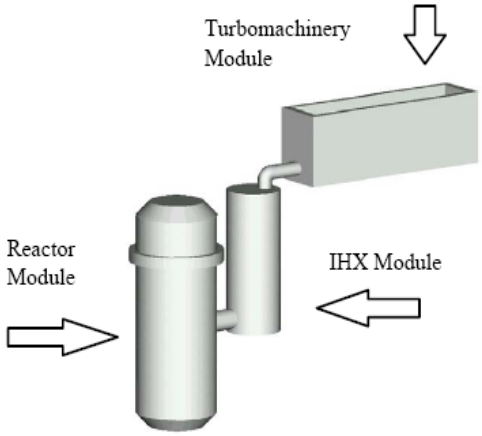

Fig. 2 Conceptual design layout of the PBMR showing design modules.[2]

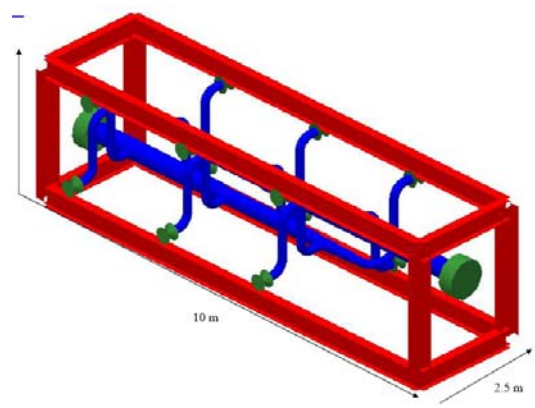

Fig. 3 Packaged module ready for shipping to site.[3]

The Sodium Advanced Fast Reactor (SAFR) required that "All major components . . . shall be sized and designed to be shop-fabricated, assembled, tested, and shipped as complete units to the plant site. Similarly, whenever possible, modular techniques shall be used to shop fabricate, assemble, test, and ship portions of systems to the maximum size compatible with construction access."[4]

Issues with multi-module certification identified by the Pebble Bed Modular Reactor (PBMR) include[5]

- establishment of a basic module configuration for the design that allows for variations in, or sharing of, common systems
- determination of the extent to which design certification safety analyses must include events affecting more than one reactor module
- specification of boundary conditions between modules such that safety considerations may be developed at the module level
- specification of interface requirements between reactor modules
    - level of detail
    - balance between design certification and combined operating license applications
- identification of restrictions which may be necessary during the construction and startup of a given module to ensure the safe operation of any module already operating

The design requirements for the PRISM advanced liquid metal reactor required that the individual modules be designed to be removable and replaceable without impact on other operating modules.[6] Thus, General Electric was not only concerned with the original construction but with maintenance and operability as the plant aged.

2.1.2 All systems located outside containment are potential candidates for sharing

Many of the systems that should be evaluated for serving both units (i.e., those systems that can be shared) will not show up in a probabilistic risk assessment (PRA). For example, the Browns Ferry Nuclear (BFN) power station, consisting of three General Electric supplied boiling-water reactors (BWRs), shares almost 40 systems between the 3 units, of which 21 are covered in the multi-unit PRA. Thus, Browns Ferry shares safety-related systems, auxiliary systems, and buildings. These systems could have a big impact on cost. For example, the potable water system in the AP1000, which consists of a 10K gallon capacity tank, is designed to furnish water for domestic use and human consumption. Since it does not provide a safety function, the potable water system is not included in a PRA. However, a single system should be able to serve both units at a twin-unit station.

It is recognized that if a 2x capacity system is built up front for the first unit, then the entire cost is an upfront cost. In addition, any shared systems need to be designed to be able to support both (if 2) units simultaneously (e.g., a shared tank must have sufficient inventory for EACH unit).

2.2 Safety

PRAs and accident analyses are two different approaches to measuring the safety of a facility. Both are required and both can provide useful insights into plant safety.

2.2.1 Probabilistic Risk Assessment

The multi-unit/shared systems aspect of the IRIS creates the potential for anywhere from one unit up to several twin-unit plant arrangements to be located at the same site. The PRA needs to account for the risk of multiple twin-units, which is comparable to the light-water reactor PRA case of a multi-unit site. The existence of twin-units increases the likelihood of scenarios that impact a single unit independently, and creates the potential for scenarios that may dependently involve both units.

The twin-units of an IRIS station will be coupled much closer than those at current generation multi-unit sites. Any PRA for IRIS will likely need to perform a twin-unit PRA, regardless of the sharing of systems. Consider the experience of the Tennessee Valley Authority (TVA) while seeking approval of its Individual Plant Examination (IPE) for Unit 3 at Browns Ferry.

On November 23, 1998, the Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 88-20, "Individual Plant Examination for Severe Accident Vulnerabilities," that requested all licenses to

- perform a systematic examination to identify any plant specific vulnerabilities to severe accidents, and
- identify and review proposed plant improvements (design changes and changes to operating procedures, maintenance, surveillance, training, or staffing).

Supplement 1 to GL 88-20 contained NUREG-1335, "Individual Plant Examination: Submittal Guidance," that requested licensees to submit "the dependency matrix for all supporting systems and front-line systems . . . This also includes dependencies caused by systems that are shared among multi-unit plants."

In 1990, NRC noted that the three units at BFN share important safety-related systems. NRC requested TVA provide expanded PRAs for Units 1 and 3 that evaluated the entire site as a whole, taking into account the risk significant combinations of unit operational status.

In early 1992, TVA provided NRC with[7]

- a list of systems shared between the BFN units and a description of their shared functions,
- a review of the systems that are shared between the BFN units. TVA identified 10 systems whose ability to reliably perform their safety function could be challenged due to the impact of system sharing. The most limiting configuration for the 10 shared systems occurs when all three units are in operation.
- An assessment that a complete loss of offsite power and loss of plant air are the two initiating events that could directly result in the shutdown of all three units.

In September 1994, NRC issued the Safety Evaluation closing GL 88-20 for Unit 2 only. It stated that TVA's IPE submittal addressed only single unit operation of BFN Unit 2. According to the NRC, closure of IPE activities for the Browns Ferry site was dependent upon receipt and review of TVA's multi-unit PRA. According to TVA, GL 88-20 is 15 years old and no longer represents current utility and NRC policy. Instead of an IPE, licensees are performing Level 1, 2, and 3 PRAs to support risk-informed operations.

Although TVA disagreed with the staff position in that it believed it expanded the scope of NRC required review because only a summary of unit differences was all that was necessary to satisfy GL 88-20, TVA submitted a multi-unit PRA for all three units in April 1995. Thus, Browns Ferry has an IPE for Unit 2 and a multi-unit PRA that covers Units 1, 2, and 3.

Based on TVA's experience, a PRA evaluating not only each single unit but the entire plant may be required.

There are several important issues to consider in evaluating the combinations and arrangements of shared systems.

Two operating units provide four possible plant operating configurations:

1. Units 1 and 2 operating
2. Unit 1 operating and Unit 2 shut down
3. Unit 1 shut down and Unit 2 operating
4. Units 1 and 2 shut down

Similarly, three operating units provide eight possible plant operating configurations.

2.2.2 Accident analysis

As in the case of any multi-unit plant where the units are contiguous or adjacent, the design must be evaluated with respect to possible influences of one unit on the others through the various coupling mediums that exist in the design. An obvious coupling medium is simply the atmosphere, in the sense that a radioactive release from one unit could require emergency action to protect operators at a contiguous or nearby unit. Another coupling is the interconnected electrical grid. In this case, a hypothetical accident on one unit must be considered as having the potential, however small, of causing a general electrical system loss of offsite power, thereby inducing trips and shutdowns of all reactors that are connected to that system. A less obvious coupling may be a conventional service system, such as compressed air or any of several conventional service water systems, the failure of which might either directly or indirectly cause the unit(s) to shut down. Couplings from intense natural events such as tornadoes, earthquakes, and floods must be considered in these designs, as well as intense unnatural events such as fire, steaming, flooding, and collision or impact from mechanical failures. For BFN, TVA evaluated such couplings under the following categories of events[8]:

- Normal Events: These are events that occur regularly and frequently under normal operating conditions. For a three-unit plant, any or all of the units may be operating at any power level or may be shut down. However, it is unlikely that all units will be shut down at the same time.
- Expected Events: These events are expected to occur infrequently during the life of the plant. They may be due to such causes as operator error, failure in a unit or plant system, normal weather extremes, and transmission line faults.
- Postulated Events: These events are postulated to occur during the life of one of several plants from such causes as severe floods, minor operational basis earthquakes, or tornadoes; or severe unnatural events such as fire, mechanical failure of small equipment or failure in equipment and components in the conventional nonredundant systems of this plant.

- Limiting Postulated Events: Certain limiting events are postulated in order to establish the limiting design conditions for the protection and engineered safeguards systems. They have potential for serious public damage and plant damage extending to the complete functional loss of a unit or the plant. These events are not expected to occur during life of the plant. They include such events as recirculation line failure, design basis earthquake associated with recirculation line failure, sustained loss of offsite power, or curtailed flow of water due to earthquake damage combined with loss of downstream dams. The demands on the unitized and the shared systems under these categories of events vary according to the operational state of the individual units.

The design of shared features at Browns Ferry is based on all combinations of states possible with three units, except that, in the case of accidents, accidents are limited to only one of three reactors.

Certain shared plant systems, such as electric power and ventilation systems, have a significant importance in that they must be in essentially continuous operation under all of the event categories and plant states listed above. The design includes features which recognize the importance of continuity of these services with due regard for allowable outage or repair times.

The scope of TVA's analysis includes all plant features in which unit sharing and interaction are a significant consideration, except that it does not include those aspects of design and operation associated with refueling operations.

"Unit sharing" implies a coupling of some kind between two or three operating reactors. Where appropriate, the multi-unit PRA for BFN also briefly discusses shared system interactions with each other.

At BFN, the criteria for the design of shared systems are as follows:[7]

a. Only one of the three units shall be assumed to be in a loss-of-coolant accident or post-accident recovery mode at any point in time; however, the system shall be adequate to address accident signals, spurious and real, in all three units in any order (i.e., real followed by spurious or spurious followed by real).
b. The most severe combinations of thermal, hydraulic and electrical loads associated with the various combinations of plant states shall be assumed to establish the design basis for capacity of the shared systems, consistent with the assumption in (a) above.
c. Shared engineered safeguards and supporting service systems shall provide reliable and redundant services to the units and to the plant in all combinations of modes of operation of the units.
d. Systems which are potentially contaminable by accident consequences such as residual heat removal shall not be shared except in the extremely degraded post accident cases described in (e) and (f) below.
e. It shall be assumed that gross flooding of the basement areas could occur as a consequence of torus or torus header piping failure below the water line in the torus in the long term following a loss-of-coolant accident. Additional core damage shall be prevented under these circumstances. The effect of gaseous releases shall not be accommodated in this design; the sole intent shall be to provide continuous core cooling to preclude further core damage.
f. Post-accident core cooling shall be provided in the long term after all of the core standby cooling systems in the accident unit have failed because of flooding or other cause. For this case, long-term post-accident cooling is defined to begin no sooner than 10 minutes after the accident.

g. Incidents or accidents in one unit shall not directly influence the operation of the other units; they may indirectly cause or require shutdown of the other units. Examples of such incidents are loss of offsite power and compressed air.
h. Control rooms and other common rooms requiring temporary occupancy in order to operate or shut down the plant shall be protected by appropriate shielding and atmospheric filter systems, so that the most severe radiation release event from one unit shall not cause excessive dose levels in these rooms.
i. Common plant features shall be designed to resist the most severe postulated natural phenomena, such as tornado, flood, and earthquake, without causing fuel damage, except that fuel damage is permissible in the event of a maximum postulated earthquake coincident with recirculation line failure on one unit. The combination of concurrent earthquake and recirculation line failure would be a beyond design basis event. The design shall allow for a random single failure in addition to those which might occur as the result of these conditions, such as pump losses from possible missile impact or water header failures which could cause both partial loss of cooling water and flooding of critical features.
j. Redundant shared systems shall be appropriately isolated and/or separated to avoid loss of essential services from single intense events, including failure of such systems.
k. Shared systems which are in the category of engineered safeguards or their auxiliary supporting systems shall be protected from failure of lower class systems or structures.

The accident analysis must consider the certification of a single unit with proposed unit boundary conditions for accident analyses, shared system analyses, common-cause failures, and systems interactions.

There is a need to determine the extent to which design certification safety analyses must include events affecting more than one unit. For example Generic Issue 130 is concerned with vulnerabilities at multi-unit sites from emergency service water (ESW) system failures.

There is also a need to specify boundary conditions between units such that safety considerations may be developed at the unit level.

Finally, there is a need to specify interface requirements between reactor units.

2.2.3 Nonsafety-Related Systems

With the reliance on passive safety systems, some active safety-related systems have been reclassified as nonsafety-related systems in the advanced reactors. Facilities such as the AP1000 and ESBWR still take credit for these nonsafety-related systems in their accident analyses and PRAs.

Maloperation of other shared systems may challenge the protection and safeguards systems of the units or plant by requiring unit trips and shutdown cooling; however, these systems may not be required to safely shut down the plant. While some of these systems are used during normal shutdown, loss of these systems will not preclude going to cold shutdown. Examples of common plant features that have little, if any, connection with reactor operation and safety considerations would be the service and office buildings, hydrogen trailer port, and gatehouse.

2.3 Operability

Safety-related structures, systems, and components (SSCs) should not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair the ability to perform the safety functions including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

Normal startup and shutdown of each reactor module should be accomplished without adversely affecting the state (operating or shutdown) of any other reactor module.

2.3.1 Cross-ties

It is of interest for the PRA to identify a bounding configuration that presents the largest challenge to the shared systems. This will change as units are built. For example, cross-ties are nonexistent when Unit 1 is completed and Unit 2 is still under construction. When both units are completed however, systems that were dedicated 100% to Unit 1 may now be shared with Unit 2.

One of the strengths of PRA is the ability to evaluate system interactions and dependencies. Many plants have found that providing additional capabilities to cross tie and back up systems can be beneficial, particularly for systems like electric power and cooling systems. For example, one plant site with two units identified the use of a cross-connection between the units' service water systems could provide additional protection in the event service water cooling was lost at one unit. Crediting this cross-connection capability resulted in a 25% reduction in the CDF for each unit.[9]

Electrical systems also play an important role in reducing risk. Some plants, particularly multi-unit sites, have the capability to crosstie ac and/or dc power supplies to back up the loss of the primary supply. In one case, the provision of a crosstie capability between the 4kV electrical safety buses at two units resulted in a 35% reduction in CDF. In addition, the same plant found that supplying a small generator onsite could provide a backup to some essential plant instrumentation power supplies. This change resulted in an additional 66% reduction in CDF for a total reduction of nearly a factor of five.

IRIS does not need cross-ties between units to lower its core damage frequency because it is already so low. Thus, the issue is not one of employing cross-ties to reduce the CDF but, rather, one of sharing systems to reduce costs, while maintaining a safe and reliable plant.

The usefulness of cross-ties should not be dismissed however, without evaluation. For example, cross-ties could be beneficial by allowing the use of a single standby swing pump to service more than one unit.

2.3.2 Flexible plant configurations

Conceptual plant configurations include single unit and twin unit plants. However, possible configurations for analysis should include sharing systems between multiple units, either as dual unit, triple unit, quadruple unit plants, etc. (Fig. 4).

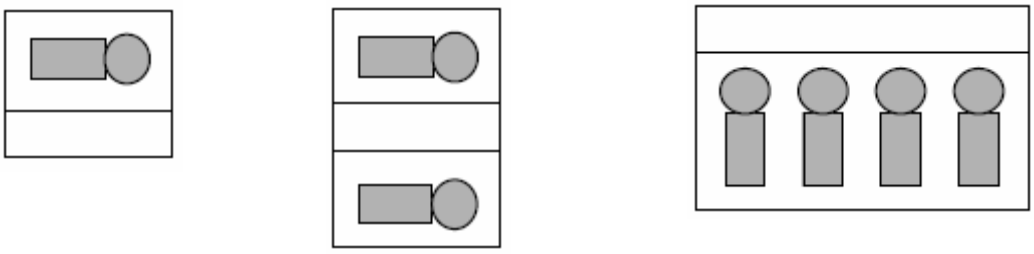

Fig. 4 Flexible plant configurations showing single, twin, and 4-single unit plant configurations.[5]

With a collection of single unit stations, the sharing of structures and systems may be minimized. The units are constructed in a “slide-along” manner with first unit(s) put into operation while subsequent unit(s) under construction. The plant maintains its compact footprint (330m-by-480m site for 3 modules, 1005 MWe). The goals are to minimize construction time and provide generating capability as soon as practical, and to maximize workforce efficiency and significantly shorten second and third unit construction time.

For a site with multiple twin unit stations, the shared structures and systems are maximized (includes fuel handling/spent fuel pool and support systems in auxiliary building). The sharing of a control room with separate safety and protection systems is not limited to twin unit stations however. Twin-units could be constructed in a “slide-along” manner with the first unit put into operation while the second unit is still under construction. Multiple single units could be constructed in the same manner. The goals are to maximize the shared equipment and minimize costs. For example, minimizing operations and maintenance (O&M) costs and effort by sharing workforce while still benefiting from the slide-along construction method to shorten the construction time of the second (or successive) unit(s).

2.3.3 Construction

Sequestration of operating units should be such that units under construction do not impact operations.

Any possible restrictions that may be necessary during the construction and startup of a given unit to ensure the safe operation of any unit already operating need to be identified.

The site layout should enable operation of completed power blocks while construction of additional power blocks is in progress. Modules can be spatially separated with each power block functionally independent of the other power blocks.

Balance of plant (BOP) structures and overall plant layout should include sufficient space for separation by construction barriers to allow continued plant operation during sequential plant expansion.

The control room should be located to facilitate incremental addition of power blocks as well as servicing the reactor service buildings and the remote shutdown facility. The shutdown and control system for each module shall be separate; however, common data highways may be used in interfacing with the control room.

2.3.4 Maintenance

The sharing of systems must consider space limitations for ease of maintenance. More importantly however, is the potential effect of maintenance on a system that supports two (or more) units and the operability of those units. The units need to be able to operate with the system shutdown for maintenance of the systems would require at least two trains such that one train can be in operation or standby while the other train is out of service for maintenance.

2.3.5 Review of LERs

The licensee event reports (LERs) for dual unit plants with shared systems need to be reviewed to identify initiators or system shutdowns or malfunctions that affected multiple units. One example is NRC's concern of ESW system failures at multi-unit sites.

2.4 Licensing Considerations

The regulatory basis recognizes both modular reactors and the sharing of SSCs between units. Large light-water reactor (LWR) plants have been designed, licensed, and operated with shared SSCs, including safety-related systems such as ESW and structures such as the control room. Therefore, there is already a basis for sharing of systems for Title10, Part 52 of the Code of Federal Regulations (10 CFR 52).

2.4.1 Code of Federal Regulations

Overall, the regulations will require a description of the various configurations, including variations in or sharing of common systems and their interactions. Licensees will also have to demonstrate that sharing will not significantly impair an SSC's ability to perform its safety function(s) and will not prevent an orderly shutdown of remaining module(s). Regulatory criteria of interest, specifically for multi-unit sites, are given below.

> 10 CFR 50.2, *Station Blackout*—At multi-unit sites, where the combination of emergency ac power sources exceeds the minimum redundancy requirements for safe shutdown (non-design basis accident or non-DBA) of all units, the remaining emergency ac power sources may be used as alternate ac power sources provided they meet the applicable requirements. If these criteria are not met, station blackout must be assumed on all the units.[10]
>
> 10 CFR 52.47(b)(3)— An application seeking certification of a modular design must describe the various options for the configuration of the plant and site, including variations in, or sharing of, common systems, interface requirements, and system interactions. The final safety analysis and the probabilistic risk assessment should also account for differences among the various options, including any restrictions which will be necessary during the construction and startup of a given module to ensure the safe operation of any module already operating.
>
> 10 CFR 50.34(b)(6)(vii)— On or after February 5, 1979, applicants who apply for operating licenses for nuclear power plants to be operated on multi-unit sites shall include an evaluation of the potential hazards to the SSCs important to safety of operating units that may result from construction activities, as well as a description of the managerial and administrative controls to be used to provide assurance that the limiting

conditions for operation are not exceeded as a result of construction activities at the multi-unit sites.[11]

10 CFR 50, Appendix A, *Criterion 5—Sharing of structures, systems, and components.* Structures, systems, and components important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.[12]

10 CFR 50, Appendix A, *Criterion 19—Control room*. A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions, including loss-of-coolant accidents. Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, for the duration of the accident. Equipment at appropriate locations outside the control room shall be provided (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures.

2.4.2 Generic Issues

In 2001, the NRC amended its criteria and guidance for risk-informed technical screening of generic issues applicable to reactor and materials facilities. The technical screening is to evaluate the possible safety implications of generic issues in a disciplined, quantitative manner. The screening of generic issues uses risk insights related to changes in core damage frequency, large early release frequency, and the product of the frequency of an accident and the averted public dose (person-rems). Although some of the issues have been dropped from further consideration, the reasons they were dropped are as informative as the issues themselves. Generic issues of interest to a multi-unit plant are given below.

Generic Issue 130, “Essential Service Water Pump Failures At Multiplant Sites (Rev. 2),” is concerned with the potential core damage vulnerability resulting from failure of the ESW system in selected multi-unit plants. These multi-unit plants are all twin pressurized-water reactor (PWR) designs that have only two ESW pumps per unit (one per train) backed up by a unit crosstie capability. This generic issue applies to seven U.S. sites (14 units). The study established and analyzed the core damage vulnerability and identified potential improvements for the ESW system. It obtained generic estimates of the risk reduction potential and cost effectiveness of each potential improvement. The analysis also investigated the cost/benefit aspects of selected combinations of potential improvements. In resolving the issue, the NRC staff addressed the loss of ESW at seven multi-unit plant sites (all Westinghouse dual-unit plants). The affected units have similar ESW system designs with two trains per unit: one pump per train with a crosstie between units. The issue was resolved with technical specification (TS) and emergency procedures.[13]

Generic Issue 162, “Inadequate Technical Specifications for Shared Systems at Multiplant Sites when One Unit is Shut Down,” was identified as a result of the potential for some shared systems to have an inadequate number of available components or inadequate flow rates when one unit is shut down and the other unit is operating.

> Systems having the potential for inadequate TS when they are shared include the service water system, HVAC systems for shared control room areas and switchgear rooms, onsite ac and dc system, and the component cooling water systems. The issue was dropped from further review because NRC research programs or activities were developed to address it.[14]

The Chernobyl Unit 4 accident was a prompt critical reactivity excursion that occurred when the operators reduced power to well below the permissible safe operating level and, at the same time, neglected to follow low power operating procedures. Unit 4 shared a site with Units 1, 2, and 3 and was contiguous with Unit 3 with which it also shared some common elements. All three of the other units were exposed to some danger from the accident. Fires aggravated the accident and complicated its management and consequences. Some relevant findings concerning the accident are given below.

> ITEM CH2.3: MULTIPLE-UNIT PROTECTION—The radioactive gas and smoke released during the accident at Chernobyl Unit 4 spread to the other three operating units at the site. The airborne radioactive material was transported to the other units through a shared ventilation system as well as by way of general atmospheric dispersion paths. This raises the question of how accidents at one unit of a multi-unit site affect the remaining units and additional questions of how these effects may be compounded when SSCs are shared between units. This item consists of four recommendations that are described below.[15]
>
> 1. ITEM CH2.3A: CONTROL ROOM HABITABILITY—The objective of this issue is to estimate what effects an accident at one unit of a multi-unit site could have upon the ability of site personnel to maintain the remaining units in a safe condition, to identify potential new requirements that would decrease those effects, and to assess the safety advantages of such requirements in relation to the disadvantages of their imposition.
> 2. ITEM CH2.3B: CONTAMINATION OUTSIDE CONTROL ROOM—The objective of this issue is to identify all plant areas to which human access would be necessary to either manage an accident at an affected unit or to maintain other units at a multi-unit site, to assess the dose consequences to personnel performing needed tasks within those areas, and to identify any potential measures for further reducing those consequences which could be justified by virtue of improved risk.
> 3. ITEM CH2.3C: SMOKE CONTROL—This issue calls for assessment of the risk significance of smoke propagation from one unit to an adjacent unit and to address the question of whether additional protection/requirements should be developed.
> 4. ITEM CH2.3D: SHARED SHUTDOWN SYSTEMS—This issue involves determination of requirements for shared systems and preparation of guidance on the use of shared systems as part of the severe accident policy implementation.

2.4.3 Regulatory Guidelines

The NRC’s Regulatory Guide series provides guidance to licensees and applicants on implementing specific parts of the NRC's regulations, techniques used by the NRC staff in evaluating specific problems or postulated accidents, and data needed by the staff in its review

of applications for permits or licenses. The NRC has addressed the sharing of electric power systems at multi-unit plants in its regulatory guide series.

> Regulatory Guide 1.12, "Nuclear Power Plant Instrumentation For Earthquakes," describes the seismic instrumentation that is acceptable to the NRC staff for satisfying the requirements of 10 CFR 50.20 and 1 CFR 50, Appendix S. At multi-unit sites, instrumentation in addition to that installed for a single unit will not be required if essentially the same seismic response is expected at the other units based on the seismic analysis used in the seismic design of the plant. However, if there are separate control rooms, annunciation should be provided to both control rooms.[16]
>
> Regulatory Guide 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants," reflects the NRC's desire to minimize undesirable interaction effects at those plants that share onsite emergency electric power systems. (A device is considered to be shared among units if it is designed to perform the same function in all units as required.) NRC's regulatory position is that[17]
>
> 1. dc systems in multi-unit nuclear power plants should not be shared, and
> 2. each unit should have separate and independent onsite emergency and shutdown electric systems, both ac and dc, capable of supplying minimum engineered safety feature (ESF) loads and the loads required for attaining a safe and orderly cold shutdown of the unit, assuming a single failure and loss of offsite power.
>
> Regulatory Guide 1.191, "Fire Protection Program For Nuclear Power Plants During Decommissioning and Permanent Shutdown," recommends that the fire hazards analysis should evaluate the risks of exposure associated with fires at the same site or at nearby facilities. Consideration should be given to the effects of a fire on shared systems for multi-unit sites and to the potential for fires to propagate from one facility to the other. Decommissioning activities should not be allowed to affect the water supply to the operating units or the fire water supplies and distribution systems that are shared at multi-unit sites and the capability to isolate the units should be maintained.[18]

3. IDENTIFICATION OF PLANT SYSTEMS THAT CAN BE SHARED

The economic benefits of sharing structures and systems between units at multiunit plant sites have long been recognized. The Point Beach nuclear power station was the first two-unit plant to use many common facilities and shared auxiliary systems. The construction permit for Point Beach Unit 1 was granted in July 1967 with initial criticality and first power to the electric grid in November 1970. Point Beach Unit 2 went critical in May 1972 and was available for commercial operation in October 1972.[19] Since then, there have been about 35 other dual- or tri-unit plants constructed. Because IRIS is being designed by Westinghouse, it is of interest to note that 18 of these multiunit plants are of Westinghouse design.

3.1 What is "Sharing"

Before a system can be identified as a potential system that can be shared between units, what must be understood is what is meant when a system or structure is "shared."

There are different types of sharing. The first type of sharing is that of a *single system* that supports both units simultaneously. Examples are a single station-blackout diesel generator that is shared between units, a fire protection system that surrounds the perimeter of the plant site, and a radioactive waste disposal system that collects the waste for the site.

Another type of sharing is where full capacity, *independent systems* at each unit that can be *cross-connected* to support the other unit if necessary. An example of this type of sharing is the standby coolant supply system that provides the capability to crosstie selected portions of the residual heat removal (RHR) systems between units.

Similar to that above is where full capacity, *independent systems* at each unit *share* standby or spare equipment. An example of this type of sharing is an installed spare pump or swing pump that is shared between units.

The sharing of "systems" also includes the sharing of *buildings or structures* between units. Examples of shared structures include the sharing of the control room. It is not unusual for dual-unit plants to share auxiliary, service, and/or turbine buildings. Examples of shared structures include the cooling, circulating, or service water intake structures; cooling towers; large capacity or seismically qualified tanks such as boric acid tanks, raw water storage tanks, condensate storage tanks, boron recovery tanks, primary grade water storage tanks; and spent fuel pools or new fuel storage areas.

A cursory review of dual-unit plants shows that there is not a "one size fits all" answer to the sharing of structures and systems between units (Table 1). Even plants with the same vendor differ significantly in the number and type of systems and structures that are shared.

Table 1 Number of shared systems and structures at a sample of dual- and tri-unit sites

Plant	NSSS Vendor	Number of shared structures	Number of shared systems
ANO 1 & 2	CE, B&W	22	19
Oconee 1, 2, & 3	B&W	3	25
Palo Verde 1 & 2	CE	1	6
Browns Ferry 1, 2, & 3	GE	13	29
Hatch 1 & 2	GE	11	10
Sequoyah 1 & 2	GE	7	10
Beaver Valley 1 & 2	W	11	15
Comanche Peak 1 & 2	W	5	15
Cook 1 & 2	W	7	20
North Anna 1 & 2	W	14	16
Surry 1 & 2	W	15	14

3.2 Candidate List of Systems to Consider for Sharing

The investigation of options for sharing systems at IRIS is based on the AP1000 balance-of-plant systems. This assumption was made because the IRIS design is not sufficiently mature to have a design of any of its secondary and tertiary systems. This is a reasonable assumption because although the primary systems are vastly different, primary systems are not good candidates for sharing.

Because IRIS is a Westinghouse-designed plant, it was assumed that the secondary and tertiary systems would have similar designs, names, and functions as those for the AP1000. The AP1000 provides a master list of ~100 systems and each was considered to be potentially available for sharing.

To determine which systems are legitimate candidates for sharing at an IRIS multi-unit plant, it was assumed that those systems located outside of the containment building for the AP600 and AP1000 plant designs would be similar to those of IRIS. Based on the plant layout for the AP1000, those systems and structures located in the auxiliary building, radwaste building, annex building and turbine building (i.e., outside containment) are candidates for sharing (Fig. 5). Structures and systems by location are shown in Fig. 6.

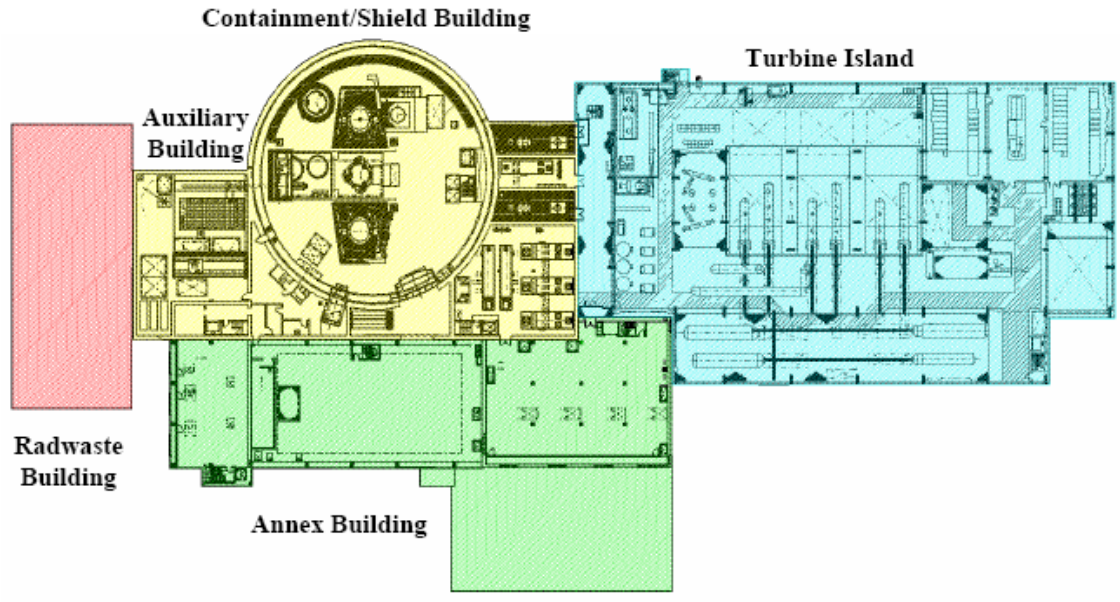

Fig. 5 Plant building arrangement for the AP1000.[20]

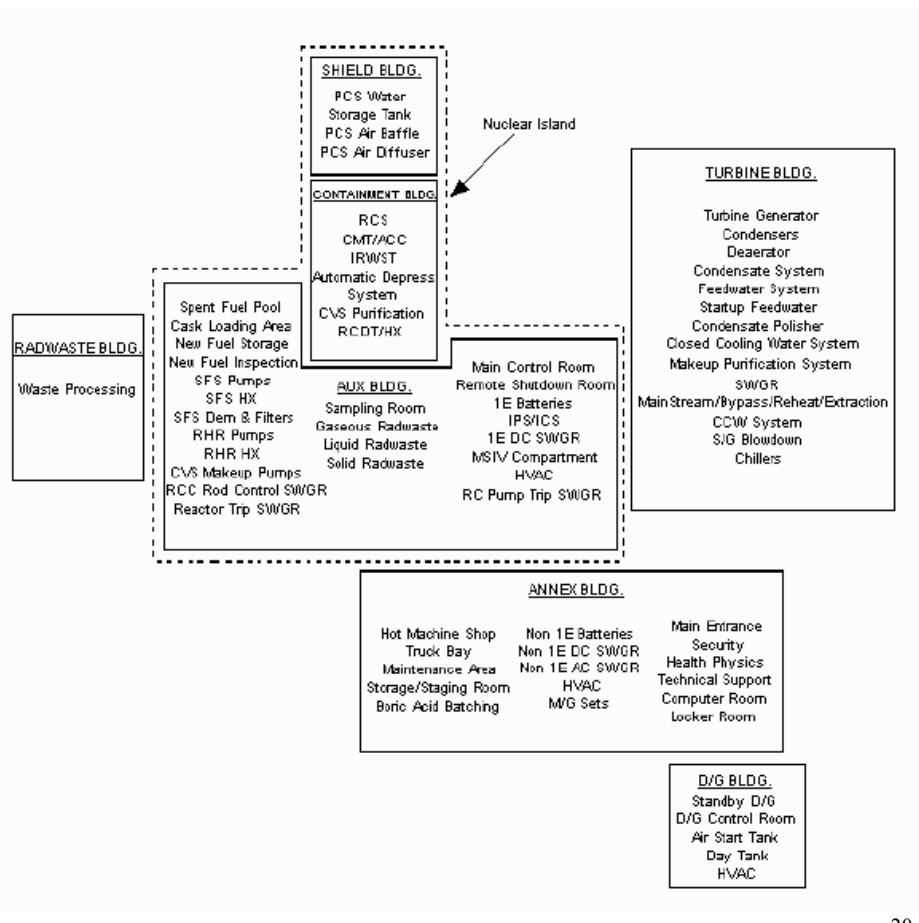

Fig. 6 Plant system location by building for the AP1000.[20]

Determining what systems can be shared first requires that a list of all systems be compiled. The *Design Control Document* for the AP1000 lists 88 system designators (e.g., the designator for the component cooling water system is CCS) that represents about 95 systems (see Appendix. A). [The passive core cooling system accounts for five systems in the PRA.]

Again, the four factors that influence the sharing of systems at multiunit plants are economics, safety, operability, and licensing considerations. Many of the systems selected as available for sharing may not impact safety or operability but could impact cost. Not all of these systems are needed to respond to an initiating event or to mitigate the failure of safety systems. For the AP600 and the AP1000, about 24 systems are associated with mitigating functions for the initiating events and these are the systems that are addressed in the PRA. Thus, around three out of four of the systems in a plant are not addressed in the plant's PRA (Table 2). As a result, restricting the selection of systems that can be shared based on those that are addressed in the PRA would limit the value of the study. Therefore, in order to optimize safety and operations while minimizing cost, numerous system arrangements will need to be evaluated and metrics developed to account for economics, safety, operability, and licensing considerations.

Table 2 Number of shared systems between units modeled in the plants PRA

Plant	NSSS Vendor	Number of systems*		
		Per unit	Shared between units**	Shared systems* in PRA
Cook 1 & 2	W		20	7
Oconee 1, 2,& 3	B&W	94	25	7
Browns Ferry 1, 2, & 3	GE		29	21

*numbers are approximate
**The systems and structures shared between units are reported in that plant's Updated Final Safety Analysis Report

Because the AP600 and AP1000 plants are designed as stand-alone plants and were not designed to share any systems between units, the safety analysis reports for several dual- and tri-unit plants were reviewed to identify those type of systems that are shared (see Appendix B). Because of the wide variety of system that are shared between units, a detailed review of the AP1000 and three other plants was performed to identify if the systems

- are important to safety and are addressed in the plants PRA or IPE
- are shared between units, or
- have cross-ties within or between units.

The three plants are Cook Units 1 and 2 (Westinghouse PWRs); Oconee Units 1, 2, and 3 (Babcock and Wilcox PWRs), and Browns Ferry Units 1, 2, and 3 (General Electric BWRs). The results of this review are provided in Appendix C. The next step in this project is to process the

lists of candidate systems for sharing (see Appendices A, B, and C) and qualitatively evaluate the benefits and drawbacks.

3.3 Measure of How Well Objectives Can Be Met

The objectives for a twin unit IRIS plant were evaluated against currently licensed and operating plants. Each objective, with an assessment of its feasibility, is addressed below.

- *Operation of a completed twin unit is initiated while construction of subsequent twin(s) proceeds in a "slide-along" manner*
  - Both U.S. and international experience shows that one unit at a dual-unit plant can begin operation while the other unit is under construction.
  - The risk profile of the operating unit will change once the second unit is completed because some systems that were dedicated to a single unit become shared once construction is completed and the other unit begins operating.

- *Each twin unit is completely independent from the subsequent twin(s)*
  - This objective is similar to the groups of CANDU units at Bruce A and B and Pickering A and B. Each group of plants contains four units; each unit in the group became operational within several years of each other.

- *Each reactor within a twin has its own turbine generator, condenser, and feed and steam systems, both housed in a single turbine generator building*
  - Similar to the IRIS twin unit reference plant, in the licensed operating plants reviewed, the main and auxiliary feedwater systems, the condensate system, and the main steam systems are not shared between units.
  - An auxiliary steam system that supplies steam and hot water for building HVAC systems is typically a shared system.
  - A common arrangement for dual unit plants is for the sharing of the auxiliary building and/or turbine building (in some cases, the turbine hall is located within the Auxiliary Building).

- *Each turbine generator, condenser, and feed and steam systems are coupled to their own nonsafety service water and main circulating water mechanical draft cooling towers*
  - Service water, circulating water, and the mechanical draft cooling towers are dedicated systems that are not shared.
  - Many of the service water systems at dual unit plants are shared:
    - "shared" via a cross-tie (e.g., ESW, NSW, and CCW at Cook 1 and 2);
    - share a common supply header (e.g., CCW, LPSW, and HPSW at Oconee 1, 2, and 3); or
    - share tanks or the spare pumps (e.g., the CC system at Oconee).

  - Plants with cooling ponds, lakes, or rivers use those large bodies of water as a source of water and as an ultimate heat sink and are shared between units (as are the pump houses).

- Some plants share the cooling towers; the viability of sharing a mechanical draft cooling tower is an option that should be reviewed because of its potential economic impact.

- *Within a twin unit, many systems, functions, and physical facilities are shared, including control room, fuel handling area with refueling machine and spent fuel pit and cask loading facility, radwaste treatment, support systems, and switchyard*

  - Many of the tertiary support systems (i.e., those systems not coupled in some manner to the cooling of the reactor core) are prime candidates for sharing.
  - These support systems not only include the fuel handling system and the radwaste treatment systems, but systems such as the makeup water treatment system, fuel pool cooling and cleanup system, fire protection system, and potable and sanitary water system.
  - Shared structures include not only the control room, fuel handling area, and switchyard, but the plant stack; water intake structures; diesel generator; and control, service, and water treatment buildings.

- *Within the twin unit, separate safety-grade power supplies, protection cabinets and switchgear, and electrical systems are maintained*

  - The advanced reactors, such as the AP1000 and the ESBWR, have minimized the amount of safety-grade power supplies because the passive systems do not require electric power, except to initiate operation.
    - Consider sharing the diesel generators; the diesel generators at the Gen III+ plants are no longer safety-related and there are fewer of them at a site.
  - Because many of the electrical systems are no longer safety-related in the Gen III+ plants, they can be shared between units at a site with minimal affect, if any, on plant safety.
    - The sharing of nonsafety-related electrical systems should still meet the criteria that separation is maintained between power supplies, protection cabinets and switchgear, and electrical systems.

4. CONCLUSIONS

The findings of this investigation, while focused on the IRIS concept as a case study, are extendable to other multi-modular reactor concepts. This report identifies those plant systems that can be considered for sharing between/among units. In addition, it provides initial identification of key considerations in the development of a decision support methodology for defining a cost effective multi-modular implementation approach that preserves the desired safety characteristics of advanced plants.

There are almost 100 systems that make up a nuclear power plant. The economies of sharing structures and systems between units can be significant. However, the proper selection of systems and structures to be shared cannot be made based on economics alone. Safety, operability, and licenseability are also factors. Yet, of the 100 systems, about three-fourths of these systems are not evaluated in the PRA. Therefore, selecting systems for sharing based on safety severely limits the benefits and savings of sharing systems.

Once the selection of possible systems available for sharing is expanded to all systems, there are numerous metrics to consider, some of which may conflict. The design needs to consider all systems located outside containment as potential candidates for sharing but must also allow for one unit to operate while another is being constructed.

The objectives for IRIS are consistent with what NRC has licensed and approved to date. This investigation shows that based on what has been licensed and approved by NRC, some systems that are currently not under consideration for sharing should be evaluated further for sharing opportunities and impacts. A potential list of systems to be shared will be completed and evaluated in the next phase of this study.

Although focused on the IRIS concept as a case study, the insights may be applicable to the AP1000 if two units are located at one site. Specific topics to evaluate and consider are that numerous systems and structures at a site are not safety related. Further, the unavailability of numerous systems does not impact the availability of a unit or plant.

Conclusions from the first phase of the assessment for sharing systems are:

- Regulations allow sharing but the safety impact must be assessed in detail;
- Decision metrics are necessary to evaluate cost, safety, reliability, and performance of shared systems;
- Primary systems are not candidates for sharing;
- The number of systems that are shared and the type of sharing directly relates to the complexity of the safety, risk, and accident assessments; and
- “Slide along” construction is a viable and proven concept.

This is the first phase of an extended study to develop a methodology for defining a multiunit sharing strategy. Follow-on activities will

- Assess the potential of all systems for sharing,
- Process the lists of candidate systems for sharing,
- Winnow the list to those systems that can impact safety or economics, and
- Qualitatively and qualitatively evaluate the benefits and drawbacks of sharing candidate systems between units.

The next step is to process the lists of candidate systems for sharing (see Appendices A, B, and C) and qualitatively evaluate the benefits and drawbacks.

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[18] U.S. Nuclear Regulatory Commission, Regulatory Guide 1.191, "Fire Protection Program for Nuclear Power Plants During Decommissioning and Permanent Shutdown."
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Appendix A

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Table A.1 List of systems in the AP1000

System	Covered in Chapter		Location
	DCD	PRA	
Reactor Coolant and Connected Systems			
Reactor Coolant System	5.1		Containment
Reactor System	5.3		Containment
Normal Residual Heat Removal System	5.4.7	17	Containment
Engineered Safety Features			
Passive Containment Cooling System	6.2.2	13	Containment Shield Building; Auxiliary Building
Containment System	6.2.3	24	Containment
Containment Hydrogen Control System	6.2.4	16	Containment
Containment Leak Rate Test System	6.2.5		Auxiliary Building
Passive Core Cooling System • passive residual heat removal • core makeup tank • accumulator • automatic depressurization system • in-containment refueling water storage tank	6.3	 8 9 10 11 12	Containment
Main Control Room Emergency Habitability System	6.4		Auxiliary Building
Instrumentation and Controls			
Reactor Instrumentation			
Protection and Safety Monitoring System	7	26	
Data Display and Processing System	7.1		
Operation and Control Centers System	7.1		
Plant Control System	7.1	28	
Diverse Actuation System	7.7	27	
Other Instrumentation			
Meteorological and Environmental Monitoring System	2.3.3		
Seismic Monitoring System	3.7.4		
Special Monitoring System	4.4.6		
In-core Instrumentation System	4.4.6		Containment
Electric Power			
Main Generation System	8.1		
Transmission Switchyard and Offsite Power System	8.2		
Onsite Standby Power System	8.2.1		Diesel Generator Building
Main ac Power System	8.3.1	21	
Grounding and Lightning Protection System	8.3.1		
Special Process Heat Tracing System	8.3.1		

Table A.1 continued

System	Covered in Chapter		Location
	DCD	PRA	
Non Class 1E dc and UPS System	8.3.2	23	
Class 1E dc and UPS System	8.3.2	22	
Auxiliary Systems			
Fuel Storage and Handling			
Mechanical Handling System	9.1		Various
Fuel Handling and Refueling System	9.1.1		Containment Auxiliary Building
Spent Fuel Pool Cooling System	9.1.3		Containment Auxiliary Building
Water Systems			
Service Water System	9.2.1	19	Turbine Building and yard
Raw Water System	9.2.1		Turbine Building and yard
Component Cooling Water System	9.2.2	18	Auxiliary Building Turbine Building
Demineralized Water Treatment System	9.2.3		Turbine Building
Demineralized Water Transfer and Storage System	9.2.4		Various
Potable Water System	9.2.5		Various
Sanitary Drainage System	9.2.6		Various
Central Chilled Water System	9.2.7	20	Various
Turbine Building Closed Cooling Water System	9.2.8		Turbine Building
Waste Water System	9.2.9		Various
Hot Water Heating System	9.2.10		Various
Process Auxiliaries			
Compressed and Instrument Air Systems	9.3.1	25	Various
Plant Gas Systems	9.3.2		Various
Primary Sampling System	9.3.3		Containment Auxiliary Building
Secondary Sampling System	9.3.4		Turbine Building
Chemical and Volume Control System	9.3.6	15	Containment Auxiliary Building Annex Building
Air-Conditioning, Heating, Cooling, and Ventilation System			
Nuclear Island Nonradioactive Ventilation System	9.4.1		Annex Building Auxiliary Building
Annex/Auxiliary Non-Radioactive Ventilation System	9.4.2		Annex Building Auxiliary Building
Radiologically Controlled Area Ventilation System	9.4.3		Annex Building Auxiliary Building
Containment Recirculation Cooling System	9.4.6		Containment
Containment Air Filtration System	9.4.7		Annex Building

Table A.1 continued

System	Covered in Chapter		Location
	DCD	PRA	
			Auxiliary Building
Radwaste Building HVAC System	9.4.8		Radwaste Building
Turbine Building Ventilation System	9.4.9		Turbine Building
Diesel Generator Building Ventilation System	9.4.10		Diesel Generator Building
Health Physics and Hot Machine Shop HVAC System	9.4.11		Annex Building
Other Auxiliary Systems			
Fire Protection System	9.5.1		Various
Communication Systems	9.5.2		
Plant Lighting System	9.5.3		
Standby Diesel and Auxiliary Boiler Fuel Oil System	9.5.4		Diesel Generator Building and Yard
Plant Security System	13.6		
Storm Drain System	None		Various
Gravity and Roof Drain Collection System	None		Various
Closed Circuit TV System	None		
Cathodic Protection System	None		
Steam and Power Conversion			
Turbine-Generator			
Generator Hydrogen and CO_2 Systems	10.2		Turbine Building
Hydrogen Seal Oil System	10.2		Turbine Building
Main Turbine and Generator Lube Oil System	10.2		Turbine Building
Main Turbine System	10.2		Turbine Building
Main Turbine Control and Diagnostics System	10.2.2		Turbine Building
Excitation and Voltage Regulation System	10.2.2		
Main Steam Supply System			
Main Steam System	10.3		Turbine Building
Steam Generator System	10.3		Containment Auxiliary Building
Other Features of Steam and Power Conversion System			
Condenser Tube Cleaning System	10.4.1		Turbine Building
Condenser Air Removal System	10.4.2		Turbine Building
Gland Seal System	10.4.3		Turbine Building
Turbine Island Vents, Drains and Relief System	10.4.3		Turbine Building
Circulating Water System	10.4.5		Turbine Building; Pump intake structure
Condensate Polishing System	10.4.6		Turbine Building
Condensate System	10.4.7		Turbine Building
Heater Drain System	10.4.7		Turbine Building
Main and Startup Feedwater System	10.4.7	14	Turbine Building
Steam Generator Blowdown System	10.4.8		Turbine Building

Table A.1 continued

System	Covered in Chapter		Location
	DCD	PRA	
Auxiliary Steam Supply System	10.4.10		Turbine Building
Turbine Island Chemical Feed System	10.4.11		Turbine Building
Radioactive Waste Management			
Liquid Radwaste System	11.2		Containment Auxiliary Building
Radioactive Waste Drain System	11.2		Auxiliary Building
Gaseous Radwaste System	11.3		Auxiliary Building
Solid Radwaste System	11.4		Auxiliary Building
Radiation Monitoring System	11.5		

Appendix B

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Table B.1 Shared structures and systems at Hatch Nuclear Plant, a GE-designed BWR

Shared System or Structure	Description
Shared structures and facilities	
Plant stack	A 120-m stack is used to discharge the off-gas of HNP-1 and HNP-2.
Intake structure	The river intake structure is shared by both HNP-1 and HNP-2. The structure houses plant service water and residual heat removal service water pumps.
Diesel generator building	The diesel generator building is designed to house the diesel generators, local control panels, and emergency switchgear for both HNP-1 and HNP-2. Each diesel generator and its control panel are physically separated from the other diesel generator units.
Control building	HNP-1 and HNP-2 are operated from a common control room. The control panels are separated and the units controlled separately.
Refueling Floor	The reactor buildings for HNP-1 and HNP-2 are separated except above the refueling floor, which is common to both units.
Service building	The service buildings that house office facilities for plant management personnel and related functions are shared by both HNP-1 and HNP-2.
Water treatment building	The water treatment building contains the well water filter and makeup dimeneralizer shared by both HNP-1 and HNP-2.
Fire protection pump house	The fire protection pump house contains fire protection equipment that is shared by both HNP-1 and HNP-2.
Independent spent fuel storage installation	The ISFSI provides additional storage of spent fuel from both HNP-1 and HNP-2 under the general license provisions of 10 CFR 72, subpart K.
Shared systems and equipment	
Auxiliary electrical power system	During normal operation, electrical power to the auxiliary loads are supplied through the unit auxiliary transformers. Each unit has one startup auxiliary transformer plus one shared startup auxiliary transformer to provide startup and shutdown power and supply the emergency busses during normal operation.
Standby ac power supply system	The standby ac power supply consists of two diesel generators for each unit plus one shared diesel generator.
Fuel pool cooling and cleanup system	The HNP-1 fuel pool cooling and cleanup system consists of two 50% trains. One 50% train is provided on HNP-2. Since both units are not refueled simultaneously, one of the HNP-1 trains can be shared during refueling of HNP-2.
Fire Protection System	The fire protection water supply system is shared by both HNP-1 and HNP-2, as shown in the *Edwin I. Hatch Nuclear Plant Units 1 and 2 Fire Hazards Analysis and Fire*

Table B.1 continued

Shared System or Structure	Description
	Protection Program (incorporated by reference into the FSAR).
Makeup Water Treatment System	The makeup water treatment system is designed to meet the treated water requirements for both HNP-1 and HNP-2.
Potable and Sanitary Water System	The potable and sanitary water system is designed to meet the requirements for both HNP-1 and HNP-2.
Plant Communication System	Internal and external systems are designed to provide convenient and effective communications among various plant buildings and locations.
Control Room Environmental Control System	The control room environmental control system supplies heating, ventilation, and air conditioning for the control room shared by both HNP-1 and HNP-2.
Main Stack Radiation Monitoring System	The main stack radiation monitoring system is shared by both HNP-1 and HNP-2.
Turbine Building Crane	The turbine building crane is shared by both HNP-1 and HNP-2.
Reactor Building Crane	The reactor building crane is shared by both HNP-1 and HNP-2.
Control Building Chilled Water System	The control building chilled water system is designed to provide chilled water to various coolers located in the control building shared by both HNP-1 and HNP-2.

Source: HNP-1-FSAR-1

Table B.2 Shared structures and systems at Sequoyah, a GE-designed BWR

Shared System or Structure	Description
Shared structures and facilities	
Control Building	There is a common control room for both units.
Auxiliary Building	
Turbine Building	
Diesel Generator Building	
Service and Office Building	
Intake Pumping Station	
ERCW Pumping Station	
Shared systems and equipment	
Chemical and Volume Control System	The CVCS shares 3 boric acid tanks and 4 boric acid transfer pumps between the two units.
Component Cooling System	There are a total of 5 component cooling system pumps and up to 3 can be shared. There are a total of 6 component cooling heat exchangers; two are shared.
Spent Fuel Pit Cooling System	The spent fuel pit is shared between units 1 and 2.
Waste Disposal System	A common Waste Disposal System is used for the two units. Each containment structure has its own reactor coolant drain tank and containment sump and each is serviced by two reactor coolant drain tank pumps. All other waste disposal equipment is sized to or contracted to adequately serve two units and common Auxiliary and Service Building.
Emergency Gas Treatment Systems	Portions of the Air Cleanup Subsystem of the Gas Treatment Systems shared components include ducting, air purification filter and absorbers, fans and flow control dampers.
Air Cleanup Systems	Portions of the Air Cleanup Subsystem of the Gas Treatment Systems shared components include ducting, air purification filter and absorbers, fans and flow control dampers.
Essential Raw Cooling Water System	The water supply and distribution system is essentially common to both units.
Standby AC power System	The Standby AC Power System supplies power to both units.
Vital 125V DC Control Power System	Four 125V Vital Batteries and Boards, each supply two static inverters of the Vital 120V AC Control Power system on each unit. A spare vital battery is also provided as needed.
Offsite Power System (Preferred Power Supply)	The offsite power grid serves as the preferred power supply for both units.

Source: Sequoyah FSAR

Table B.3 Shared structures and systems at ANO 1 and 2, CE and B&W designed PWRs

Shared System or Structure	Description
Shared structures and facilities	
Raw Water Storage Tank	
Control Room	The plant is provided with a control room located adjacent to the Unit 2 control room. The control panels and equipment are physically separated by a glass wall, eliminating interaction between the Unit 1 and Unit 2 systems. The glass wall does not extend to the ceiling so the air conditioning and ventilation systems are shared by both units.
Emergency Cooling Pond	The cooling pond serves as a heat sink for normal plant shutdown of either Unit 1 or 2, as well as the source of emergency cooling water for simultaneous shutdown of both Units 1 and 2 in the unlikely event of a loss of the Dardanelle Reservoir water inventory. Under controlled conditions, with the Dardanelle Reservoir available, the ECP may provide SW/ACW to Unit 1 with Unit 2 and/or Unit 1 providing normal makeup as necessary to preserve ECP inventory. It is sized to contain sufficient water for dissipating the total combined heat transferred to the Unit 1 and 2 Service Water Systems as a result of the DBA in one unit and a normal plant shutdown of the other unit while limiting the cooling pond temperature to a maximum of 121°F. Separate suction and discharge water lines are used for supplying pond water to the Unit 1 and Unit 2 Service Water Systems. The end of the lines terminating at the cooling pond are housed in Seismic Category 1 structures to prevent blockage of the pipe entrance and outlet.
Condensate Storage Tank	A safety grade Condensate Storage Tank is shared by ANO-1 and ANO-2. The tank is a seismic qualified source of condensate supply for the Emergency Feedwater System. Although both ANO-1 and ANO-2 are connected to the tank, only ANO-1 has taken credit for utilization of this source. ANO-2 has the capability to use this source if required.
Diesel Fuel Oil Bulk Storage Tank	
Liquid Nitrogen Storage Tank	
Clean Chemistry Laboratory, Count Room	
Turbine Building Crane, Elevator	
Intake Structure Gantry Crane	
Fuel Handling Crane (Auxiliary Building)	

Table B.3 continued

Shared System or Structure	Description
Startup Boiler	
Office Buildings	
Shops (Clean Instrument, Hot Instrument, Hot Machine, Machine, and Welding)	
Storeroom, Maintenance Facility, Warehouse, and Gas Bottle Storage	
Control Room Kitchen and Sanitary Facilities	
Post Accident Sampling System (PASS) Building	
Independent Spent Fuel Storage Installation (ISFSI)	
Low Level Radwaste Storage Building (LLRWSB)	
Railroad Spur, Access Roads, Parking Facilities	
Switchyard, Transmission Lines	
Reservoir Water Canals	
Tendon Maintenance Scaffolding	
Shared systems and equipment	
Communications Systems	
Fire Water Main and Fire Pumps	
On-Site and Off-Site Environmental Monitoring	
Sodium Bromide/Sodium Hypochlorite System	
Telemetering and Load Dispatching Equipment	
Instrument Air Systems (shared only when an abnormal situation requires cross-connecting)	
Service Air Compressor	
Breathing Air System	
Oily Water Separator	
Sewage System	
Station Security System	
High Purity Hydrogen System	
RCP Vibration Dynamic Data	

Table B.3 continued

Shared System or Structure	Description
Manager System	
Bulk Hydrazine Transfer	
Safety Parameter Display System	The SPDS is a computer-based system designed to monitor and display to the operator a concise set of parameters from which the safety status of the plant can be readily and reliably ascertained. The system functions as the SPDS for both the ANO-1 and ANO-2 Control Rooms and provides plant status information for the Technical Support Center (TSC) and Emergency Operations Facility (EOF).
Alternate ac (AAC) Power Source And Building	The AAC power source, which consists of a 4400 kW diesel generator (continuous rating) and supporting auxiliaries, is designed to manually pick up the loads on one 4160V ESF bus in either Unit 1 or Unit 2 in the event of a station blackout in either unit. Additionally, it can be connected to a non-1E bus in either unit for performance testing or peaking.
Waste Disposal System	Certain portions of the Waste Disposal System located in the auxiliary building are common for Units 1 and 2. These include: A. Solid waste handling facilities B. Laundry Waste System C. Waste and boric acid concentrators (located in Unit 2) D. Regenerative Waste System (located in Unit 2)
Electrical System	Startup Transformer 2 is common to Units 1 and 2 and is available as a standby transformer for its respective unit auxiliary or startup transformers. Its availability as an additional, independent source of power to the two sources normally provided for each unit (Unit Auxiliary and Startup Transformer 1 for Unit 1 and Unit Auxiliary and Startup Transformer 3 for Unit 2) allows operational flexibility without loss of the redundancy required for the engineered safety features power supply.
Control Room Ventilation System	There are two normal ventilation systems, one for the Unit 1 half and one for the Unit 2 half, of the common control room. The air intake into each system is monitored for radiation and chlorine. Upon receiving a high radiation or high chlorine concentration signal from any of the normal air intakes, the entire control room, both Unit 1 and Unit 2 sections, is sealed except for filtered outside air used for pressurization to minimize unfiltered air inleakage. This arrangement assures redundancy in the monitoring system. Air conditioning for both control rooms under isolated control room conditions is maintained by emergency air handling and condensing units located in Unit 2. The emergency air conditioning trains are normally powered from vital buses in Unit 2 but one train can be supplied power from a vital bus in Unit 1. Only one emergency air conditioning train is

Table B.3 continued

Shared System or Structure	Description
	required to operate during and following a shutdown of both units.

Source: ANO 2 FSAR

Table B.4 Shared structures and systems at Palo Verde, a CE-designed PWR

Shared System or Structure	Description
Shared structures and facilities	
Switchyard	A common switchyard is provided for PVNGS Units 1, 2, and 3.
Shared systems and equipment	
Station Blackout Gas Turbine Generation System	The Station Blackout Gas Turbine Generation (GTG) System is shared between units. The GTG system provides AC electrical power of sufficient capacity and reliability to operate the systems required for coping with a station blackout in any one of the units for a period of 4 hours.
Domestic water system	The Domestic Water System consists of a well water supply subsystem, a water treatment subsystem, and a storage and transfer subsystem which are shared facilities. Each PVNGS unit has a hot and cold water distribution system. Domestic water is also distributed to facilities in the water reclamation plant and the water treatment area. Waste water from operation of the treatment subsystem is directed to the water reclamation plant for recovery.
Demineralized water system	The Demineralized Water System consists of a degasifier subsystem, a demineralizer subsystem, a regeneration subsystem, a demineralized water storage and transfer subsystem, and a sulfuric acid storage and transfer subsystem. Waste water from DWS operations is directed to a spent regenerant sump, is treated in accordance with Water Reclamation Facility operating procedures, and is pumped to the Water Reclamation Facility clarifier feed sump or the trickling filter sump emergency overflow.
Sanitary treatment system	The Sanitary Drainage and Treatment System is part of the equipment and floor drainage system. The sanitary waste flows from facilities throughout the plant to the wet well at the sewage lift station. The waste is transferred from the wet well to the surge tank. In the surge tank, the waste is again aerated before being transferred to the three package sewage treatment units. Here the waste is treated and clarified. The sludge is removed, and the clarified wastewater overflows a weir into the discharge line which transports it to the chlorine contact chamber. In the chlorine contact chamber, the wastewater is chlorinated and overflows a weir into a discharge line which conveys it to the sanitary wastewater sump. Wastewater from the sanitary wastewater sump is pumped to the water reclamation plant for further treatment and reuse.
Water reclamation plant	Plant water demands for the nonsafety-related cooling water system are normally met using effluent primarily from the city of Phoenix 91st Avenue Sewage Treatment Plant with effluent input capability also from other smaller plants

Table B.4 continued

Shared System or Structure	Description
Water reclamation plant	enroute. The effluent is conveyed to the site by means of a pipeline and pumping facilities and is treated in the onsite water reclamation plant to meet plant water quality requirements. An onsite storage reservoir provides for a continuous water supply in the event of scheduled or unscheduled interruptions or reductions in the normal water source. In addition, wastewater from the sanitary wastewater sump is pumped to the water reclamation plant for further treatment and reuse.
Fire Protection System	The fire protection water supply and pumping equipment is shared by Units 1, 2, and 3. The plant two-way radio system is one of the communications means available for coordinating fire response team activities and safe shutdown activities. The plant two-way radio system is shared among all three units. Other fire protection equipment is provided for each unit individually.

Source: Palo Verde FSAR

Table B.5 Shared structures and systems at North Anna 1 and 2, Westinghouse-designed PWRs

Shared System or Structure	Description
Shared structures and facilities	
Auxiliary building	
Fuel building	
Turbine building and turbine room crane	
Service building	
Main control area	
Decontamination facility	
Office building	
General station services (nonelectrical)	
Fuel-oil system	
Service water pump house	
Waste disposal building	
Boron recovery tank building	
Waste gas decay tank vault	
Station black-out building	
Shared systems and equipment	
Electrical systems	Standby station service transformer facility
Chemical and volume control system	The chemical and volume control system 1. regulates the concentration of chemical neutron absorber in the reactor coolant to control reactivity changes 2. maintains the proper coolant inventory in the reactor coolant system for all normal modes of operation, 3. removes fission products and corrosion products from the reactor coolant during the operation of the reactor and maintains these within acceptable levels. 4. Controls the pH levels, and 5. continuously supplies filtered water to each reactor coolant pump seal, as required by the reactor coolant pump design. The centrifugal charging pumps in the chemical and volume control system also serve as the high-head safety injection pumps in the emergency core cooling system. Other than the centrifugal charging pumps and associated piping and valves, the chemical and volume control system is not required to function during a loss-of-coolant accident.
Boron recovery system	The boron recovery system is a common system serving both units. The system degasses and stores borated radioactive water letdown from the chemical and volume control system and reactor coolant drains from the vent and

Table B.5 continued

Shared System or Structure	Description
	drain system. Further processing by evaporators, filters, and demineralizers in this system produces primary-grade water and concentrated boric acid solution for station reuse or disposal. The system is either designed to allow liquid samples to be taken before the distillate is reused or to be sent to the liquid waste disposal systems.
Component cooling water system	The component cooling water subsystem, serves both reactor units, and is part of the component cooling system that also consists of the chilled water, and neutron shield tank cooling water subsystems. The component cooling water subsystem is an intermediate cooling system and transfers heat from heat exchangers containing reactor coolant or other radioactive liquids to the service water system. The Component Cooling Water Subsystem itself consists of four subsystems shared between units. The maximum heat load occurs during the initial stages of residual heat removal during a reactor unit cooldown. The design basis of the component cooling water subsystem is a fast cooldown of one unit while maintaining normal loads on the other unit. Three component cooling water subsystems are required to accomplish this function. The fourth subsystem is a spare and may be out of service indefinitely. Therefore, to ensure cooldown of one unit within 16 hours and maintain the other unit in normal full power operation, three of the four subsystems are required. This system serves no accident mitigation functions. The subsystem is considered operable in standby conditions because it can be easily placed in service quickly.
Containment Atmosphere Cleanup System	This system consists of two identical portable skid-mounted hydrogen recombiners, two hydrogen analyzers, two purge blowers, and associated piping systems. The system is common to both reactor units. The containment atmosphere cleanup system draws the containment atmosphere through either of two open lines in the containment. These lines are also used as inlets for the containment vacuum pumps. The gases pass through the hydrogen recombiner where any hydrogen present is converted to water vapor and returned to the containment. When the system is used to purge the containment, the gas is discharged to the atmosphere through the gaseous waste disposal system. The hydrogen recombiner system is designed to maintain the hydrogen concentration in the containment structure below 4 volume percent following a DBA.

Table B.5 continued

Shared System or Structure	Description
Fuel pit cooling and refueling purification systems	The fuel pit cooling and refueling purification system removes residual heat from spent fuel stored in the spent-fuel pit. This system is also used to purify and maintain optical clarity of the spent-fuel pit water, the water in either reactor refueling cavity, and the refueling-water storage tanks. This system is common to both units and normally serves only the spent-fuel pit. During and immediately after refueling, the system also performs a purification function of the refueling water. Although shared by both units, the safety function is not affected by an accident in either unit. The spent-fuel coolers, part of the component cooling water system, are supplied by a common header connected to both units by isolation valves and a return header also connected to both units by isolation valves. This arrangement allows common equipment to be operated from either or both units' component cooling water supply. In the event of an accident, cooling water can be provided to the non-accident plant and to the common equipment by the system supplying the plant not involved in the accident.
Sampling system	Sampling systems include a normal operations sampling system and a post-accident sampling system. The sampling system is designed to provide a means of obtaining representative primary and secondary liquid and gaseous samples as required to effectively monitor the operation of both units. The system provides samples from numerous different sources, which can be sampled either locally or at sample sinks in the auxiliary building and service building. When appropriate, samples originating within the containment are joined into a common header before penetrating the containment wall in order to limit the number of penetrations. Air-operated valves inside the containment are used to select and control the appropriate sample. All other samples are manually controlled at one of the sample sinks or a local sample point.
Vent and drain system	The vent and drain system collects potentially radioactive fluids and gases from various systems and discharges them either to the waste disposal systems liquid or gaseous or to the boron recovery system. Liquids from potentially contaminated sources, other than those originating in the reactor coolant system, are transferred to the high-level waste drain tanks in the liquid waste disposal system via the high-level-waste drain header. Liquids collected in the high level waste drain tanks are processed through filters and demineralizers, pumped to the low level waste drain tanks,

Table B.5 continued

Shared System or Structure	Description
	and then released if they meet release limits as specified in the Offsite Dose Calculation Manual (ODCM). If the liquids do not meet release limits, then they are reprocessed. Both containment structures, the auxiliary building, the fuel building, the decontamination building, both safeguards areas, the valve pit areas, and both incore instrumentation areas have been provided with sumps for collecting drainage. The drainage is transferred by sump pumps to either the high- or low-level-waste drain tank, depending on the activity level, from all the sumps except the decontamination building sump, which is pumped to the fluid waste treatment tank.
Service water system	The sources of service water for North Anna Units 1 and 2 are the North Anna reservoir and the service water reservoir. These two independent sources of water form the ultimate heat sink for North Anna Power Station. Service water is used as cooling water for heat exchangers that remove heat from the component cooling system, the recirculation spray subsystem, and other station applications such as main control room air-conditioning condensers, charging pump lubricating-oil and instrument air compressors. In addition, service water is provided as a backup supply to the steam generator feed system, the fuel pit coolers, and the recirculation air cooling coils. The service water system is a common system and is designed for the removal of heat resulting from the simultaneous operation of various systems and components of two units based on an accident condition service water temperature of 110°F. Untreated water, supplied from the North Anna reservoir, or treated water from the service water reservoir, is circulated by pumps through the systems and components that require an ensured supply of service water under accident conditions and other systems and components denoted in this section.
Fire protection system	The fire protection system is designed to furnish water and other extinguishing agents with the capability of extinguishing any single or probable combination of simultaneous fires that might occur at the station. The fire protection system includes the low-pressure carbon dioxide (CO2) system, the high-pressure carbon dioxide systems, the control room Halon 1301 system, and the sprinkler and water spray systems. The collective capability of the fire suppression systems is adequate to minimize potential damage to safety-related equipment and is a major element

Table B.5 continued

Shared System or Structure	Description
	in the facility fire protection program. In the event that portions of the fire suppression systems are inoperable, alternate backup fire fighting equipment is made available in the affected areas until the inoperable equipment is restored to service. Operability of the fire detection instrumentation ensures that adequate warning capability is available for the prompt detection of fires. This capability is required in order to detect and locate fires in their early stages. Prompt detection of fires will reduce the potential for damage to safety-related equipment and is an integral element in the overall facility fire protection program. The functional integrity of the penetration fire barriers ensures that fires will be confined or adequately retarded from spreading to adjacent portions of the facility.
Water supply and treatment system	The Water Supply and Treatment Systems consist of a domestic water system and a water treatment system. The Domestic Water System provides a safe and approved water supply. It consists of ground wells, a storage facility, pressure maintenance equipment, and a distribution system. Submersible pumps take suction from the wells and deliver the water to a 21,500-gallon storage tank. Two 300-gpm centrifugal booster pumps, one a 100% spare, deliver water to the distribution piping through a 4000-gallon hydropneumatic tank. The system pressure is maintained between 40 and 60 psig by a pressure maintenance system consisting of a pressure-level controller that operates the booster pump, an air compressor, and vent valve. Piping from the hydropneumatic tank supplies cold water for plumbing fixtures, safety showers, drinking water coolers, and domestic hot water storage tanks throughout the station. Domestic hot water is heated by electric heat rather than steam, and is not interconnected to any potentially radioactively contaminated system. The Water Treatment System provides water treatment by the reverse osmosis system. The flash evaporator system is obsolete and no longer used with the exception of the flash evaporator distillate pumps which are used for water transfer.
Ventilation system, other than containment ventilation	
Primary plant gas supply system	The primary plant gas supply system is designed to provide compressed nitrogen, hydrogen, and oxygen to the emergency core cooling system, reactor coolant system,

Table B.5 continued

Shared System or Structure	Description
	gaseous waste disposal system, chemical and volume control system, and boron recovery systems as needed. The primary plant gas supply system is common to both units. A high-pressure (about 700 psig) nitrogen manifold maintains the required gas overpressure in the safety injection accumulators in the safety injection system and in the pressurizer relief tank in the reactor coolant system. Lower pressure (about 100 psig) nitrogen serves the volume control tank in the chemical and volume control system and the catalytic recombiner and waste gas decay tanks in the gaseous waste disposal system. The lower pressure nitrogen can also be used to purge the gas strippers in the boron recovery system. The hydrogen supply system for the auxiliary building supplies hydrogen from a manifold that is located outside the auxiliary building in an open gas storage area. The supply consists of eight cylinders with a total capacity, when fully charged, of approximately 1550 ft3. The hydrogen is reduced in pressure by a 2000-lb to 100-lb pressure-reducing system, and the flow is limited to 20 scfm through a restriction orifice, both of which are located immediately adjacent to the hydrogen cylinders and outside the Auxiliary Building. The hydrogen is distributed in the auxiliary building to the volume control tanks located at Elevation 274 ft. and to the gas strippers at the 259-foot elevation. During normal plant operation, the supply line to the gas strippers is isolated by a normally shut valve located at the 274-foot elevation of the Auxiliary Building. The oxygen manifold provides low-pressure (about 10 psig) oxygen to the gaseous waste disposal system catalytic recombiner package. Each manifold is equipped with a pressure relief valve to release excess pressure to the atmosphere. The relief valves release above the gas storage area roof. A 1-month supply of each gas can be connected to a manifold. Storage facilities are available for an additional 3-month supply of each gas.
Auxiliary steam system	The steam ejector removes air from the containment to create the initial vacuum prior to unit operation, using 150-psig steam provided by the auxiliary steam system,

Table B.5 continued

Shared System or Structure	Description
	An auxiliary steam system distributes 150 psig to 225 psig steam throughout the station for auxiliary services via an auxiliary steam supply header, to the following: 1. Boric acid batch tank. 2. Condenser air ejectors. 3. Chilled water units. 4. Flash evaporator (not used). 5. Primary-water tank heaters. 6. Gas stripper feed heaters. 7. Boron evaporator reboilers. 8. Containment vacuum ejectors. 9. Building heating. Auxiliary steam is supplied from either the main steam or extraction steam systems, depending on turbine-generator load, or the auxiliary boilers.
Lubricating-oil system	The lubricating oil system provides the following functions: 1. Store lubricating oil. 2. Supply oil to and receive oil from the turbine-generator oil reservoir. 3. Purify a side stream of oil from the turbine-generator oil reservoir on a continuous bypass basis. 4. Clean and reclaim used oil from the storage tanks, pumping it from the “used oil” storage tank via the conditioner to the “clean oil” storage tank. The lubricating oil system consists of a 10,000-gallon turbine oil reservoir, two 16,000-gallon storage tanks, a lube-oil conditioner, a combination fill/batch cleaning pump, and a combination circulating/drain pump. The combination fill/batch cleaning pump and the two 16,000-gallon storage tanks are common to both units. The two 16,000-gallon storage tanks are normally designated “clean” and “used,” but are interchangeable.
Radioactive waste systems	

Source: North Anna 1 and 2 FSAR

Table B.6 Shared structures and systems at Beaver Valley Power Station, a Westinghouse-designed PWR

Shared System or Structure	Description
Shared structures and facilities	
Turbine Building and turbine room crane	
Auxiliary Building	
Service Building	
Lake Intake Structures	
Alternate Intake Structure	
Boron Recovery Tank Building	
Control Building	
Primary Grade Water Storage Tanks	
Meteorological Tower	
Interconnecting Tunnels	
Cooling Tower elevated release point	
Shared systems and equipment	
Compressed Air	
Ultimate Heat Sink	
Potable and sanitary Water System	
Gaseous Waste System	
Liquid Waste System	
Primary Grade Water System	
Demineralized Water Makeup System	
Make-up Water Supply and Treatment System	
Boron Recovery System	
Potable and Sanitary Water System	
Site Drainage System	
Fire Protection System	
Chlorination System	
Communications System	
Power for the Control Room Emergency Bottled Air Pressurization System	
Emergency Diesel Generators	

Source: Beaver Valley Power Station FSAR

Table B.7 Shared structures and systems at Comanche Peak, a Westinghouse-designed PWR

Shared System or Structure	Description
Shared structures and facilities	
Control Building	There is a common control room for both units.
Auxiliary Building	
Turbine Building	
Diesel Generator Building	
Service and Office Building	
Intake Pumping Station	
ERCW Pumping Station	
Shared systems and equipment	

Source: Comanche Peak FSAR

Table B.8 Shared structures and systems at Surry Power Station, a Westinghouse-designed PWR

Shared System or Structure	Description
Shared structures and facilities	
Control Building	There is a common control room for both units.
Auxiliary Building	
Turbine Building	
Diesel Generator Building	
Service and Office Building	
Intake Pumping Station	
ERCW Pumping Station	
Shared systems and equipment	

Source: Surry Power Station FSAR

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Appendix C

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Table C.1 Systems Credited in the PRA for the AP1000

AP1000	In PRA (chapter)	Cross-Tie	Comments (W)
MECHANICAL SYSTEMS			
Engineered Safety Features Systems			
Containment Hydrogen Control • Hydrogen Igniter Subsystem • Hydrogen Recombination Subsystem • Hydrogen Concentration Monitoring Subsystem	**Yes (16) (41B)**		The containment hydrogen control system consists of the hydrogen ignition subsystem, the non-safety-related hydrogen recombination subsystem, and the hydrogen concentration monitoring subsystem. The containment hydrogen control system serves the following functions: • Hydrogen concentration monitoring • Hydrogen control during and following degraded core and core melt scenarios (provided by 64 hydrogen igniters) In addition, two non-safety-related passive autocatalytic recombiners are provided for defense-in-depth protection against the buildup of hydrogen following a LOCA.
Containment Isolation	**Yes (24)**		The major function of the containment isolation system of the AP1000 is to provide containment isolation to allow the normal or emergency passage of fluids through the containment boundary while preserving the integrity of the containment boundary, if required. This prevents or limits the escape of fission products that may result from postulated accidents. Containment isolation provisions are designed so that fluid lines that penetrate the primary containment boundary are isolated in the event of an accident. This minimizes the release of radioactivity to the environment.
Incontainment Refueling Water Storage Tank (12)	**Yes (12)**		The Passive Core Cooling System uses natural circulation to pass heat to the IRWST. The IRWST then passes heat to the passive containment cooling system. The tank contains a 30-day supply of water.
Passive Core Cooling System (8) – Passive RHR (9) – Core Makeup Tank (10) – ADS (11) – IRWST (12)	**Yes (8-12)**		The Passive Core Cooling System provides emergency core cooling following postulated design basis events. The system provides the following functions: – Emergency core decay heat removal (RHR function) – Reactor coolant system emergency makeup and boration – Safety injection (SI) – Containment pH control (granulated TSP baskets)

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			The passive RHR heat exchanger is located in the IRWST and is connected directly to the RCS. The passive core cooling system can maintain safe shutdown conditions for 72 hours after an event without operator action and without both nonsafety-related onsite and offsite power.
Passive Containment Cooling	**Yes (13)**		The passive containment cooling system is an engineered safety features system that is used to reduce the containment temperature and pressure following a LOCA or MSLB accident inside containment. The passive containment cooling system also provides a source of makeup water to the spent fuel pool in the event of a prolonged loss of normal spent fuel pool cooling. The passive containment cooling system is capable of transferring heat directly from the steel containment vessel to the environment. The system makes use of the steel containment vessel and the concrete shield building surrounding the containment. The major components of the passive containment cooling system are: the passive containment cooling water storage tank that is incorporated into the shield building structure above the containment; an air baffle, located between the steel containment vessel and the concrete shield building; air inlets and an air exhaust, also incorporated into the shield building structure; and a water distribution system, mounted on the outside surface of the steel containment vessel, which functions to distribute water flow on the containment.
Auxiliary Systems			
Chemical and Volume Control	**Yes (15)**		The chemical and volume control system is designed to perform the following major functions: • Purification – maintain reactor coolant system fluid purity and activity level within acceptable limits. • RCS inventory control and makeup – maintain the required coolant inventory in the RCS, maintain the programmed pressurizer water level during normal plant operation. • Chemical shim and chemical control – maintain the RCS chemistry conditions by controlling the concentration of boron in the coolant for plant startups, normal dilution to compensate for fuel depletion and

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	Comments (W)
			shutdown boration, and provide the means for controlling the RCS pH. • Oxygen control – provide the means for maintaining the proper level of dissolved hydrogen in the reactor coolant during power operation and for achieving the proper oxygen level prior to startup after each shutdown. • Filling and pressure testing the RCS – provide the means for filling and pressure testing the RCS. The CVCS does not perform hydrostatic testing of the RCS. • Borated makeup to auxiliary equipment – provide makeup water to the primary side systems that require borated reactor grade water. • Pressurizer auxiliary spray – provide pressurizer auxiliary spray water for depressurization.
Service Water	**Yes (19)**		The service water system (SWS) provides the nonsafety-related function of transferring heat from the component cooling water system (CCS) to the surrounding atmosphere to support plant shutdown and spent fuel pool cooling. The SWS operates during normal modes of plant operation, including startup, power operation (full and partial loads), cooldown, shutdown, and refueling. The SWS consists of two 100% capacity service water pumps, automatic backwash strainers, a two-cell cooling tower with a divided basin, and associated piping, valves, controls, and instrumentation. The service water pumps, located in the turbine building, take suction from piping that connects to the basin of the service water cooling tower. Service water is pumped through strainers to the component cooling water heat exchangers for removal of heat. Heated service water from the heat exchangers then returns through piping to a mechanical draft cooling tower where the system heat is rejected to the atmosphere. Cool water, collected in the tower basin, flows through fixed screens to the pump suction piping for the recirculation through the system. The service water system serves no safety-related functions and therefore has no nuclear safety design basis.
Compressed and Instrument Air	**Yes (25)**		The compressed and instrument air system consists of 3 subsystems: instrument air, service air, and high-pressure air. Instrument air supplies compressed air for air-operated valves and dampers. Service air is supplied at outlets throughout the plant to power air-operated tools and is used as a motive

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			force for air-powered pumps. The service air subsystem is also used as a supply source for breathing air. The high-pressure air subsystem supplies air to the main control room emergency habitability system, the generator breaker package, and fire fighting apparatus recharge station. Major components of the compressed and instrument air system are located in the turbine building. The instrument air subsystem consists of two 100% capacity parallel air supply trains discharging to a common air distribution system. Two 100% capacity compressor trains are provided for the service air subsystem. These compressor trains consist of identical equipment and share a common air receiver that feeds the service air distribution system. The compressed and instrument air system serves no safety-related function other than containment isolation and therefore has no nuclear safety design basis except for containment isolation.
Plant Gas System			The plant gas system provides hydrogen, carbon dioxide, and nitrogen gases to the plant systems as required. Other gases, such as oxygen, methane, acetylene, and argon, are supplied in smaller individual containers and are not supplied by the plant gas system. The nitrogen portion of the plant gas system supplies nitrogen for pressurizing, blanketing, and purging of various plant components. The packaged nitrogen system is located inside the turbine building. The hydrogen gas portion of the plant gas system is a packaged system consisting of a liquid hydrogen storage tank and vaporizers to supply hydrogen gas to the main generator for generator cooling and to the demineralized water transfer and storage system to support removal of dissolved oxygen and to other miscellaneous services. The hydrogen supply package is located outdoors at the hydrogen storage tank area. The carbon dioxide portion of the plant gas system is a packaged system consisting of one liquid storage tank and a vaporizer, and produces gaseous carbon dioxide to purge the main generator of hydrogen and air during layup or plant outages. This packaged system is located in the turbine building.

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			The plant gas system serves no safety-related function and therefore has no nuclear safety design basis.
Fire Protection	**Yes (57)**		The primary objectives of the AP1000 fire protection program are to prevent fires and to minimize the consequences should a fire occur. The program provides protection so that the plant can be shut down safely following a fire. Fire water is supplied from two separate fresh water storage tanks. The primary fire water tank is dedicated to the fire protection system. The secondary fire water tank serves the raw water system but contains water for use by the fire protection system and the containment spray system. There are two 100% capacity fire pumps. The lead pump is electric motor-driven and the secondary pump is diesel engine-driven. A motor-driven jockey pump is used to keep the fire water system full of water and pressurized, as required. The fire water tanks are permanently connected to the fire pumps suction piping and are arranged so that the pumps can take suction from either or both tanks. A failure in one tank or its piping cannot cause both tanks to drain. Fire protection water is distributed by an underground yard main loop. The yard main includes a building interior header that distributes water to suppression systems within the main plant buildings. Indicator valves provide sectionalized control and permit isolation of portions of the yard main for maintenance or repair. An indicator valve also separates the individual fire pump connections to the main. Sprinkler and standpipe systems are supplied by connections from the yard main. Where plant areas, other than the containment and outlying buildings, are protected by both sprinkler systems and standpipe systems, the connections from the yard main are arranged so that a single active failure or a crack in a moderate energy line cannot impair both systems.
Spent Fuel Pool			The spent fuel storage facility is located within the auxiliary building fuel handling area. A gated opening connects the spent fuel pool and fuel transfer canal. The fuel transfer canal is connected to the in-containment refueling cavity by a fuel transfer tube. The spent fuel transfer operation is completed underwater, and the waterways are of sufficient depth to maintain a minimum of

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			10 feet of shielding water above the spent fuel assemblies. A metal gate with gasket assembly separates the spent fuel pool and fuel transfer canal. This allows the fuel transfer canal to be drained without reducing the water level in the spent fuel pool. During normal operation, this gate remains open and is only closed to drain the canal. The bottom of the fuel transfer canal has a drain connected to safety-related piping and isolation valves that prevents inadvertent draining after a seismic event.
Spent Fuel Pool Cooling System			The Spent Fuel Pool Cooling is typical of current PWRs. The spent fuel pool cooling system is designed to remove decay heat generated by the stored fuel assemblies from the water in the spent fuel pool this is done by pumping the high temperature water from within the fuel pool through a heat exchanger, and then returning the water to the pool. A secondary function of the spent fuel pool cooling system is clarification and purification of the water in the spent fuel pool, the transfer canal, and the refueling water. The spent fuel pool cooling system consists of two mechanical trains of equipment. The two trains share common suction and discharge headers. The spent fuel pool cooling system is designed such that either train of equipment can be operated to perform any of the functions required of the spent fuel pooling cooling system independently of the other train. One train is continuously cooling and purifying the spent fuel pool while the other train is available for water transfers, in-containment refueling water storage tank purification, or aligned as a backup to the operating train of equipment.
New Fuel Storage Area			The new fuel storage facility is located within the auxiliary building fuel handling area. The facility is protected from the effects of natural phenomena such as earthquakes. The new fuel storage pit is drained by gravity drains that are part of the radioactive waste drain system, draining to the waste holdup tanks that are part of the liquid radwaste system. These drains preclude flooding of the pit by an accidental release of water.
Refueling Canal Drains			

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
Heating, Ventilation, and Air Conditioning			The air-conditioning, heating, cooling, and ventilation system is comprised of the following systems that serve the various buildings and structures of the plant: • Nuclear island nonradioactive ventilation system • Annex/auxiliary buildings nonradioactive HVAC system • Radiologically controlled area ventilation system • Containment recirculation cooling system • Radwaste building HVAC system • Turbine building ventilation system • Diesel generator building heating and ventilation system • Health physics and hot machine shop HVAC system All HVAC is nonsafety. The safety related control room habitability is passive.
Component Cooling Water (CCW) System	**Yes (18)**		The component cooling water system is a closed loop cooling system that transfers heat from various plant components to the service water system cooling tower. It operates during normal phases of plant operation including power operation, normal cooldown, and refueling. The system includes two component cooling water pumps, two component cooling water heat exchangers, one component cooling water storage tank and associated valves, piping, and instrumentation. The system components are arranged into two mechanical trains. Each train includes one component cooling water pump and one component cooling water heat exchanger. The two trains of equipment take suction from a single return header. The surge tank is connected to the return header. Each pump discharges directly to its respective heat exchanger. The discharge of each heat exchanger is to the common supply header. Component cooling water is distributed to the components by this single supply/return header. Components are grouped in branch lines according to plant arrangement, with one branch line cooling the components inside containment. Loads inside containment are remotely isolated in response to a

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			safety injection signal which also trips the reactor coolant pumps. The Component Cooling Water System is a nonsafety-related system. This allows the elimination of a standby pump compared to current NPPs. It removes heat from various components needed for plant operation and removes core decay heat and sensible heat for normal reactor shutdown and cooldown.
Normal RHR	**Yes (17)**		The normal residual heat removal system removes heat from the RCS during shutdown operation at reduced pressure and temperature, provides low temperature overpressure protection for the RCS, and provides low-pressure makeup to the RCS and removes heat from the RCS following actuation of the ADS. The normal RHR (RNS) also provides a means for cooling the IRWST during normal plant operation.
Security			
Waste Management System (gas, liquid, solid)			
Process and Effluent Radiation Monitoring			
Equipment and Floor Drainage Systems			The equipment and floor drainage systems collect liquid wastes from equipment and floor drains during normal operation, startup, shutdown, and refueling. The liquid wastes are then transferred to appropriate processing and disposal systems. The equipment and floor drainage systems are nonsafety-related and serve no safety-related function except for the backflow preventers in the drain lines from containment cavities to the containment sump. No nuclear safety design basis is required except for the backflow preventers. Single active failures do not prevent the proper function of the system.
Primary Sampling System			The primary sampling system is a manually operated system that consists of two separate portions: the liquid sampling portion and the gas sampling portion. During normal operation, the primary sampling system collects representative samples of fluids in the RCS and auxiliary primary systems process streams and the containment atmosphere for analysis. This system includes equipment to collect representative samples of the various

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			process fluids, including RCS and containment air, in a manner that adheres to the ALAEA principles during normal and post-accident conditions. The primary sampling system also includes provisions to route sample flow to a laboratory for continuous or intermittent sample analysis, as desired. The primary sampling system has no safety-related function, other than containment isolation and therefore requires no nuclear safety evaluation, other than containment isolation.
Secondary Sampling System			The secondary sampling system monitors water samples from the condensate, feedwater, main steam, heater drain, steam generator blowdown, auxiliary steam supply, and condensate polishing systems. Continuous online secondary chemistry monitoring detects impurity ingress and provides early diagnosis of system chemistry excursions in the plant. Secondary sampling monitors send control signals to the turbine island chemical feed system that automatically injects corrosion control chemicals into the condensate and feedwater systems. Sample analysis data from the continuous analyzers is recorded using computer systems that also provide trending capability of the measured process parameters. Measurements are used to automatically control condensate and feedwater system pH and dissolved oxygen levels by chemical addition. Samples are analyzed and the results are used for automatic or manual control of the plant secondary water chemistry. After being analyzed, pure samples are returned to the condensate system. Sample lines containing reagents and those from sink drains are collected in the waste water system and processed for disposal. Each sample line ahs a grab sampling capability for laboratory analysis. The secondary sampling system serves no safety-related function and therefore has no nuclear safety design basis.
Seismic Monitoring System			
Demineralized Water Treatment System			The demineralized water treatment system receives water from the raw water system, processes this water to remove ionic impurities, and provides

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			demineralized water to the demineralized water transfer and storage system.
Demineralized Water Transfer and Storage System			The demineralized water transfer and storage system receives water from the demineralized water treatment system, and provides a reservoir of demineralized water to supply the condensate storage tank and for distribution throughout the plant. Demineralized water is processed in the demineralized water transfer and storage system to remove dissolved oxygen. In addition to supplying water for makeup of systems that require pure water, the demineralized water is used to sluice spent radioactive resins from the ion exchange vessels in the chemical and volume control system, the spent fuel pool cooling system, and the liquid radwaste system to the solid radwaste system. The demineralized storage tank has a capacity of ~100,000 gallons. The condensate storage tank has a capacity of 485,000 gallons.
Central Chilled Water System	**Yes (20)**	**Yes**	The central chilled water system provides chilled water to the cooling coils of the supply air handling units and the unit coolers of the plant HVAC systems. It also supplies chilled water to the liquid radwaste system, gaseous radwaste system secondary sampling system, and the temporary air supply units of the containment leak rate test system. The high capacity subsystem consists of two 100% capacity chilled water pumps, two 100% capacity water-cooled chillers, a chemical feed tank, an expansion tank, and associated valves, piping, and instrumentation. The subsystem is arranged in two parallel mechanical trains with common supply and return headers. Each train includes one pump and one chiller. A cross-connection at the discharge of each pump allows for either pump to feed a given chiller. A bypass line maintains a constant chiller flow rate as the load demand changes. The chiller condensers are supplied with cooling water from the component cooling water system. The high capacity subsystem components are located in the turbine building. The low capacity subsystem consists of two 100% capacity chilled water loops. Each loop consists of a chilled water pump, an air-cooled chiller, an expansion tank and associated valves, piping, and instrumentation. The subsystem is

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			arranged in two independent trains with separate supply and return headers. The subsystem is provided with a common chemical feed tank. The subsystem provides a reliable source of chilled water to the main control room and technical support center HVAC subsystem, and the Class 1E electrical equipment room HVAC subsystem. This system configuration provides 100% redundancy during normal plant operations and following the loss of offsite power. The air-cooled chillers of the low capacity subsystem are located on the auxiliary building roof. The chilled water pumps and expansion tanks are located in the auxiliary building below the chillers. The central chilled water system serves no safety-related function other than containment isolation, and therefore has no nuclear safety design basis except for containment isolation.
Sanitary Drainage			The sanitary drainage system is designed to collect the site sanitary waste for treatment, dilution and discharge. The sanitary drainage system collects sanitary waste from plant restrooms and locker room facilities in the turbine building, auxiliary building, and annex building, and carries this waste to the treatment plant where it is processed. The sanitary drainage system does not service facilities in radiologically controlled areas. The sanitary drainage system has no safety-related function and therefore requires no nuclear safety evaluation. There are no interconnections between this system and systems having the potential for containing radioactive material.
Potable Water			The potable water system is designed to furnish water for domestic use and human consumption. The source of water for the potable water system is the raw water system. The potable water system consists of a potable water storage tank, two potable water pumps, a jockey pump, a distribution header around the power block, hot water storage heaters, and necessary interconnecting piping and valves. Disinfection is provided upstream of the potable water storage tank. The potable water storage facility consists of a carbon steel tank with capacity less than 10,000 gallons and coated interior which stores water for distribution throughout the plant.
Waste Water			The waste water system collects and processes equipment and floor drains

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			from nonradioactive building areas. Wastes from the turbine building floor and equipment drains (that include laboratory and sampling sink drains, oil storage room drains, the main steam isolation valve compartment, auxiliary building penetration area and the auxiliary building HVAC room) are collected in the two turbine building sumps. Drainage from the diesel generator building sumps, the auxiliary building sump-north (a nonradioactive sump) and the annex building sump is also collected in the turbine building sumps. The turbine building sumps provide a temporary storage capacity and a controlled source of fluid flow to the oil separator. In the event radioactivity is present in the turbine building sumps, the waste water is diverted from the sumps to the liquid radwaste system for processing and disposal. A radiation monitor located on the common discharge piping of the sump pumps provides an alarm upon detection of radioactivity in the waste water. The radiation monitor also trips the sump pumps and the waste water retention basin pumps on detection of radioactivity to isolate the contaminated waste water. Provisions are included for sampling the sumps. The turbine building sump pumps route the waste water from either of the two sumps to the oil separator for removal of oily waste. The diesel fuel oil area sump pump also discharges waste water to the oil separator. A bypass line allows for the oil separator to be out of service for maintenance. The oil separator has a small reservoir for storage of the separated oily waste which flows by gravity to the waste oil storage tank. The waste oil storage tank provides temporary storage prior to removal by truck for offsite disposal. The waste water from the oil separator flow by gravity to the waste water retention basin for settling of suspended solids and treatment, if required, prior to discharge. The waste water basin transfer pumps route the basin effluent to either the circulating water cooling tower basin or t5o the plant outfall, depending on the quality of the water in the waste water retention basin. The condenser waterbox drains are routed directly to the waste water retention basins. The waste water system serves no safety-related function and therefore has no

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			safety-related design basis.
Turbine Building Closed Cooling Water System			The turbine building closed cooling water system provides chemically treated, demineralized cooling water for the removal of heat from nonsafety-related heat exchangers in the turbine building and rejects the heat to the circulating water system. The system consists of two 100% capacity pumps, three 50% capacity heat exchangers (connected in parallel), one surge tank, one chemical addition tank, and associated piping, valves, controls, and instrumentation. Heat is removed from the turbine building closed cooling water system by the circulating water system via the heat exchangers. During normal operation, one turbine building closed cooling water system pump and two heat exchangers provide cooling to the components. The other pump is on standby and aligned to start automatically upon low discharge header pressure. Also during normal operation, leakage from the system will be replaced by makeup from the demineralized water transfer and storage system through the automatic makeup valve. Makeup can be controlled either manually, or automatically upon reaching low level in the surge tank.
Hot Water Heating System			The hot water heating system supplies heated water to selected nonsafety-related air handling units and unit heaters in the plant during cold weather operation and to the containment recirculating fans coil units during cold weather plant outages. During normal plant operation, the hot water heating system maintains acceptable design ambient air temperatures in various areas throughout the plant. During plant outages in cold weather, the hot water heating system supplies hot water to the plant chilled water piping serving the containment building recirculation fan coil units to maintain acceptable ambient air temperatures inside containment. The hot water heating system serves no safety-related function and therefore has no nuclear safety design basis.
Communication System			The communication system provides effective intraplant communications and effective plant-to-offsite communications during normal, maintenance, transient, fire, and accident conditions, including loss of offsite power. The communication system consists of the following subsystems: • Wireless telephone system

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			• Telephone/page system • Private automatic branch exchange (PABX) system • Sound-powered system • Emergency offsite communications • Security communications system The communications system allows each guard, watchman, or armed response individual on duty to maintain continuous communication with an individual in each manned alarm station and with other agencies both onsite and offsite. This is accomplished by both the PABX system and the wireless communications system. Each system can provide these communication functions.
Plant Lighting System			The plant lighting system includes normal, emergency, panel and securing lighting. The normal lighting provides normal illumination during plant operating, maintenance, and test conditions. The emergency lighting provides illumination in areas where emergency operations are performed upon loss of normal lighting. The panel lighting in the control room is designed to provide the minimum illumination required at the safety panels.
Standby Diesel and Auxiliary Boiler Fuel Oil System			The standby diesel and auxiliary boiler fuel oil system serves no power generation function. Its function is to store and transfer fuel oil for the onsite standby diesel generators and the auxiliary boiler. The system is designed to meet the following requirements: • Provide a supply of fuel sufficient to operate each diesel generator at continuous rating for 7 days • Provide a 7-day fuel supply for auxiliary boiler operation, with half of the required fuel stored in each tank • Provide a 4-day fuel supply for the two ancillary diesel generators. The standby diesel generator and auxiliary boiler fuel oil system consists of two fuel oil storage tanks, a diesel generator fuel oil transfer system, an auxiliary boiler fuel oil supply system, and an ancillary diesel generator fuel oil supply system. Two fuel oil storage tanks are provided, one for each of the standby diesel generators. Both tanks also provide fuel oil for the auxiliary boiler. Diesel fuel oil

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	Comments (W)
			for the diesel generator is reserved by tapping auxiliary boiler fuel oil from elevated nozzles above the diesel generator storage level.
Steam and Power Conversion Systems			
Main Steam			The function of the main steam supply system is to supply steam from the steam generators to the high-pressure turbine over a range of flows and pressures covering the entire operating range from system warmup to maximum calculated turbine conditions. The main steam supply system includes the following major components: • Main steam piping from the steam generator outlet steam nozzles to the main turbine stop valves • One main steam isolation valve and one main steam isolation valve bypass per main steam line • Main steam safety valves • Power-operated atmospheric relief valves and upstream isolation valves
Startup Feedwater	**Yes (14)**	**Yes**	The startup feedwater system supplies feedwater to the steam generators during plant startup, hot standby and shutdown conditions, and during transients in the event of main feedwater system unavailability. The startup feedwater system is composed of components from the AP1000 main and startup feedwater system and the steam generator system. Startup feedwater is defined to be feedwater that passes through the startup feedwater control valves, and can be supplied from either of two sources. Startup feedwater can be supplied by a booster/main feedwater pump drawing from the deaerator storage tank and delivering through cross connect piping to the startup feedwater header, or, startup feedwater can be supplied by one or both startup feedwater pumps drawing from the condensate storage tank and delivering to the startup feedwater header. The startup feedwater header is defined to be the common segment of startup feedwater piping downstream of the startup feedwater pumps. The booster/main feedwater pumps are part of the condensate and feedwater system. The cross connection piping between

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			the main feedwater pump discharge header and the startup feedwater header contains a check valve and a nonsafety-related, air-operated isolation valve. The check valve prevents the startup feedwater pumps from supplying the main feedwater header, and the isolation valve automatically closes upon a main feedwater isolation signal to isolate the main feedwater system from the startup feedwater system. Passive Cooling Systems remove the need for an Emergency Feedwater System. During shutdown operations, the SGS removes decay heat by delivery of startup feedwater to the steam generator and venting of steam from the steam generators to the atmosphere.
Auxiliary Steam System			The auxiliary steam system provides the steam required for plant use during startup, shutdown, and normal operation. Steam is supplied from either the auxiliary boiler or the main steam system. The auxiliary boiler is located in the turbine building. The system consists of steam generation equipment and distribution headers. Condensate from the condensate storage tank is chemically treated and pumped to the auxiliary boiler deaerator where oxygen and non-condensables are removed using auxiliary steam. The auxiliary boiler feedwater pumps deliver condensate from the auxiliary boiler deaerator to the auxiliary boiler. A feedwater control valve, located in the feedwater piping, regulates water level in the auxiliary boiler. Feedwater flow is proportional to auxiliary boiler steaming rate. Steam generated by the auxiliary boiler is supplied to the plant auxiliary steam distribution piping. The auxiliary steam system serves no safety-related function and therefore has no nuclear safety design basis.

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
Turbine Island Chemical Feed System			The turbine island chemical feed system injects required chemicals into the condensate, feedwater, auxiliary steam, circulating water, service water, demineralized water treatment, and potable water systems. The components for the turbine island chemical feed system are located in the turbine building. The turbine island chemical feed system serves no safety-related function and therefore has no nuclear safety design basis.
Main Feedwater and Condensate Systems	**Yes (14)**		The condensate and feedwater system supplies the steam generators in a closed steam cycle using regenerative feedwater heating. The condensate and feedwater system is composed of the condensate system, the main and startup feedwater system, and portions of the steam generator system. The condensate system collects condensed steam from the condenser and pumps condensate forward to the steam generator system using high-pressure main feedwater pumps. The steam generator contains the safety-related piping and valves that deliver feedwater to the steam generators. The condensate and feedwater systems are located within the turbine building, and the steam generator system is located within the auxiliary building and containment. The main portion of the feedwater flow originates from condensate pumped from the main condenser hotwell by the condensate pumps. The main condenser hotwell receives makeup from the condensate storage tank.
Steam Generator Blowdown System		**Yes**	The steam generator blowdown system assists in maintaining acceptable secondary coolant water chemistry during normal operation and during anticipated operation occurrences of main condenser inleakage or primary to secondary steam generator tube leakage. It does this by removing impurities that are concentrated int eh steam generator. The steam generator blowdown system accepts water from each steam generator and processes the water as required. The safety-related portion of each blowdown line is part of the steam generator system. The safety-related design bases are a follows: • The system is provided with two isolation valves on each steam generator. These valves isolate the secondary side of the steam generator to preserve the steam generator inventory. This action provides a heat sink for a safe shutdown or design basis accident mitigation. It also provides isolation of nonsafety-related portions of the system.

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			The system consists of two blowdown trains, one for each steam generator. A crosstie is provided to process blowdown from both steam generators through both heat exchangers during high capacity blowdown from one steam generator.
Plant Heating Steam System			
Circulating Water			The circulating water system supplies cooling water to remove heat from the main condensers, the turbine building closed cooling water system heat exchangers, and the condenser vacuum pump seal water heat exchangers under varying conditions of power plant loading and design weather conditions. The circulating water systems consists of three 33-1/3-percent capacity circulating water pumps, one hyperbolic natural draft cooling tower, and associated piping, valves, and instrumentation. Makeup water to the circulating water system is provided by the raw water system. In addition, water chemistry is controlled by the turbine island chemical feed system. The three circulating water pumps take suction from the circulating water intake structure and circulate the water through the turbine building closed cooling water system, the condenser vacuum pump seal water heat exchangers, and the tube side of the main condenser and back through the piping discharge network to the cooling tower. The natural draft cooling tower cools the circulating water by discharging the water over a network of baffles in the tower. The water then falls through fill material to the basin beneath the tower and, in the process, rejects heat to the atmosphere. Provision is made during cold weather to direct a portion of the circulating water flow into freeze-prevention spray headers on the periphery of the cooling tower. Air flowing through the peripheral spray is thus heated and allows deicing in the central cooling tower spray baffles. The flow to the cooling tower can be diverted directly to the basin, bypassing the cooling tower internals. This is acci8omplished by opening the bypass valve

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			while operating one of the circulating water pumps. The bypass is normally used only during plant startup in cold weather or to maintain circulating water system temperature above 40°F while operating at partial load during periods of cold weather.
Condensate Polishing System			The condensate polishing system can be used to remove corrosion products and ionic impurities from the condensate system during plant startup, hot standby, power operation with abnormal secondary cycle chemistry, safe shutdown, and cold shutdown operations.
STRUCTURES			
Containment			
Turbine Building			
Service Building			
Auxiliary Building			
Fuel Handling Area			
Screenhouse			
Lake Intake Structures			
ELECTRICAL			
Emergency Diesel Generators			The diesel generator is able to reach rated speed and voltage and be ready to accept electrical loads within 120 seconds after a start signal (15 second requirement on current PWR emergency DGs). Each diesel generator unit is sized to supply power to the selected nonsafety-related electrical components.
Standby Diesel Generators			Two onsite Standby DGs support 6900 Vac bus 1 & 2 and 2 of 4 480 Vac load centers.

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	Comments (W)

Electric power system – 4160 VAC
Electric power system – 600 VAC
Electric power system – 480 VAC
Electric power system – 120 VAC
	Yes (21)		Main ac Power System (ECS)
			• Provides bulk electrical power
			  – 6.9 kV, 480 V, 120/208 V, 60 Hz
			• Normal power supply from main generator
			• Preferred power supply is offsite source through main and auxiliary transformers
			• Maintenance power supply is through reserve auxiliary transformer
			• Standby power source is two standby diesel generators (6900 Vac)
			• Six 6.9 kV Buses
			  – Two backed by standby diesel generators
			  – Four supply the reactor coolant pumps

Electric power system – Class 1E VDC	**Yes (22)**		The Class 1I dc and UPS system provides reliable power for the safety-related equipment required for the plant instrumentation, control, monitoring, and other vital functions needed for shutdown of the plant. In addition, the Class 1E dc and UPS system provides power to the normal and emergency lighting in the main control room and at the remote shutdown workstation. There are four independent, Class 1E 125 Vdc divisions, A, B, C, and D. Divisions A and D are each comprising one battery bank, one switchboard, and one battery charger. Divisions B and C are each composed of two battery banks, two switchboards, and two battery chargers. The first battery bank in each of the four divisions are designated as 24-hour battery banks and provide power to the loads required for the first 24 hours following an event of loss of all ac power sources concurrent with a design basis accident. The second battery bank in divisions B and C are designated as 72-hour battery banks and are used for those loads requiring power for 72 hours following the same event. No load shedding or load management

Table C.1 continued

AP1000	In PRA (chapter)	Cross-Tie	**Comments** (W)
			program is needed to maintain power during the required 24-hour safety actuation period. A single spare battery bank with a spare battery charger is provided for the Class 1E dc and UPS system. For the Class 1E dc system, the 24-hour and the 72-hour battery banks are housed in the auxiliary building in ventilated rooms apart from the chargers and distribution equipment. Each of the four divisions of dc systems are electrically isolated and physically separated to prevent an event from causing the loss of more than one division.
Electric power system – Non-Class 1E VDC	**Yes (23)**	**Yes**	The non-Class 1E dc and UPS system consists of the electric power supply and distribution equipment that provide dc and uninterruptible ac power to the plant non-Class 1E dc and ac loads that are critical for plant operation and investment protection and to the hydrogen igniters located inside containment. The non-Class 1E dc and UPS system is comprised of two subsystems representing two separate power supply trains. The subsystems are located in separate rooms in the annex building. Each subsystem consists of separate dc distribution buses. These two buses can be connected by a normally open circuit breaker to enhance the power supply source availability. Each non-Class 1E dc distribution subsystem bus has provisions to allow the connection of a spare non-Class 1E battery charger should its non-Class 1E batter charger be unavailable due to maintenance, testing, or failure.

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Table C.2 Systems Credited in the PRA for Cook 1 and 2

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
MECHANICAL SYSTEMS				
Engineered Safety Features Systems				
Containment Spray	**Yes**	**No**	**No**	The containment spray system is required in the event of a loss of coolant accident or a main steam line break accident inside containment where containment pressure rises above 2.9 psig. The containment spray system consists of two 100% capacity, independent flow trains at each unit.
Containment Equalization (Air Recirculation) / Hydrogen Skimmer System	**Yes**	**No**	**No**	The containment air recirculation and hydrogen skimmer system circulates the containment atmosphere between upper and lower containments following a LOCA and prevents the accumulation of hydrogen in restricted areas within containment following a LOCA. The system consists of two redundant independent systems and is normally in standby until actuated by a hi-hi containment pressure signal or manually from the control room.
Emergency Core Cooling	**Yes**	**No**	**No**	There are 4 accumulators per unit, one attached to each RCS cold leg. In both the low- and high pressure injection modes, the RHR provides coolant from the RWST to the RCS cold legs. During the recirculation phase, the RHR system takes coolant from the containment sump and injects it into the RCS cold legs.
Hydrogen Igniter (DIS) System	**Yes**	**No**	**No**	The hydrogen igniter system, also known as a distributed ignition system (DIS) uses glow plugs located throughout the containment building to limit post-accident hydrogen concentrations. The hydrogen igniter system is a two-train system employing a total of 70 igniter assemblies located throughout the containment building.
Auxiliary Systems				
Chemical and Volume Control	**No Check?**	**No**	**Yes**	The chemical and volume control (CVCS) system provides a means for the injection of soluble neutron absorber in the form of boric acid solution, chemical additions for corrosion control and reactor coolant cleanup and degasification. This system also provides a means to add makeup water

Table C.2 continued

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
Chemical and Volume Control	**No Check?**	**No**	**Yes**	to the reactor coolant system, reprocess water letdown from the RCS, provide seal water injection to the reactor coolant pump seals, and fill and hydrostatically test the RCS. A cross-tie on the discharge of the DVDSA charging pumps, from one unit to the other, provides emergency flexibility. The cross-tie lines contain manual valves which are closed during normal operation.
Post-Accident Containment Hydrogen Monitoring	**No**	**Yes**	**No**	The post-accident hydrogen monitoring system (PACHMS) is comprised of two sampling-analyzing-control trains. Each train has two subsystems – the hydrogen analyzer panels and the remote control panels. The hydrogen analyzer panels for each unit are located outside the containment wall in a "controlled access" area in the Auxiliary Building. The four remote control panels, two per unit, are located below the spent fuel pool in the Auxiliary Building. The PACHMS can take samples from nine locations within the reactor containment building; after analysis the sample is returned to the containment.
Essential Service Water	**Yes**	**Yes**	**Yes**	The ESW system is shared by both units. The two main headers are served by 2 pumps and each header in turn, serves half of the system load in each unit. The 2 headers are arranged such that a rupture in either header will not jeopardize the safety functions of the system.
Nonessential Service Water	**Yes**	**Yes**	**Yes**	The nonessential service water (NESW) system is a shared system that provides lake water for cooling and makeup water to numerous plant systems and components. The system consists of 4 NESW supply pumps, each with an automatic backwashing duplex strainer. During normal two-unit full power operation, the NESW system is shared between Unit 1 and Unit 2 with 3 of 4 NESW pumps needed to supply required flow. The 4th pump and strainer combination is provided for standby service as an installed spare. Two NESW pumps are located in each unit. Each pump can take suction from their respective circ water discharge tunnel and, by means of a

Table C.2 continued

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
				cross-tie line, each can also take suction from the other unit's circ water intake or discharge tunnel.
Compressed Air	**Yes**	**Yes**	**Yes**	The compressed air system has 2 plant air compressors (PACs), each capable of supplying the total compressed air demand for both units. One PAC, plant air receiver, and plant air after-cooler is located in each unit. Each plant air receiver supplies its own plant air header in the aux building; however, the shared turbine building plant air header may be supplied from either plant air receiver. Additionally, each unit has a control air compressor (CAC) that is capable of supplying that unit's control air (instrument air) needs.
Fire Protection	**No**	**Yes**	**No**	The fire protection water system is designed so that the fire pumps, water storage tanks and associated equipment are common to both units. Any pump is capable of supplying water to any automatic system, regardless of unit, and either control room can automatically start all three primary pumps. However, it is also possible to completely isolate one unit from the other hydraulically and electrically and operate each independently. In this manner, the equipment from one unit can be used and support the other unit, but should severe damage occur to the fire system in one unit, the fire system for the other unit can be isolated and will continue to function.
Spent Fuel Pool	**No**	**Yes**	**No**	Each unit has its own fuel handling equipment within its containment and an independent fuel transfer mechanism. Other fuel handling equipment used in and around the spent fuel pool is shared. Up to 3420 fuel assemblies may be stored and still retain capacity to store up to an additional 193 fuel assemblies that corresponds to a complete unloading of one unit.
Spent Fuel Pool Cooling System	**No**	**Yes**	**No**	The spent fuel pool cooling system is designed to remove the heat generated by stored spent fuel elements. The system serves the spent fuel pool which is shared between the two units. The system design incorporates two separate cooling trains sharing a common return line into the spent fuel pool. There is also a tie line that connects the two independent cooling trains. This tie line allows cross-tying the two independent trains of the cooling system if a pump and a heat exchange in different trains malfunction. Component cooling water

Table C.2 continued

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
				cools the heat exchanger.
New Fuel Storage Area	**No**	**Yes**	**No**	Each unit has its own fuel handling equipment within its containment and an independent fuel transfer mechanism. Other fuel handling equipment used in and around the spent fuel pool is shared. New fuel assemblies are received and transferred to the spent fuel pool or new fuel storage vault. The new fuel storage vault is sized for storage of the fuel assemblies and components associated with the replacement of up to 144 assemblies fro either or both units. Prior to initial core loading for Unit 1 assemblies in excess of the number which could be accommodated in the new fuel storage area were stored in the dry spent fuel pool. For Unit 2, temporary storage facilities were established adjacent to the new fuel storage area. (Use of the new fuel storage vault is not required. New fuel may be temporarily stored in the spent fuel pool or directly transferred to the refueling cavity.)
Refueling Canal Drains	**Yes**	**No**	**No**	Three refueling canal drains (2-12" and 1-10") are used to return containment spray water injected into upper containment back to the lower containment sump. During refueling outages these drains are covered to allow filling the refueling canal for fuel transport from the reactor to the spent fuel pool. Prior to startup, the converse are removed.
Heating, Ventilation, and Air Conditioning	**No**	**Yes**	**Yes**	The auxiliary building is shared between both units. The auxiliary building ventilation systems consist of engineered safety features ventilations system (one per plant unit), fuel handling area ventilation system (one shared system), general ventilation systems (one per unit with cross-tie), and general supply system (one per plant unit).
Component Cooling Water (CCW) System	**Yes**	**Yes**	**Yes**	The CCW is a support system to the ESF system and is required for post-accident removal of decay heat. Two completely independent, parallel headers are available for heat removal. An installed spare maintenance pump is available as a replacement for either unit's CCW system. The two headers are normally cross-tied through the miscellaneous services header, but after an accident occurs, the headers are separated by the operator and function as independent systems.
Security				
Waste Disposal System	**No**	**Yes**	**No**	

Table C.2 continued

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
Radiation Monitoring	**No**	**Yes**	**No**	
Seismic Monitoring System	**No**	**Yes**	**No**	
Make-up Water Supply and Treatment System	**No**	**Yes**	**No**	
Steam and Power Conversion Systems				
Main Steam	**Yes**	**No**	**No**	The main steam system is used to remove decay heat via the SGs, isolate the SGs in the event of a steam line rupture or a SG tube rupture, and supplies steam to drive the turbine-driven aux FW pump.
Auxiliary Feedwater	**Yes**	**No**	**Yes**	The primary source of water for the AFW system is from that unit's 500,000 gallon CST. An emergency backup supply is the opposite unit's CST through normally closed CST cross-tie valve. A cross-tie between units is provided; the IPE models AFW flow of 450 gpm to 2 SGs on the other unit.
Auxiliary Steam System	**No**	**Yes**	**No**	The auxiliary steam system generates and delivers auxiliary steam to various systems when required. This system supplies steam to systems that cannot get steam from the main steam system; it also supplies steam and hot water for building HVAC systems.
Main Feedwater and Condensate Systems	**Yes**	**No**	**No**	These systems automatically maintain the water level of the SGs during normal operation. Upon receipt of a FW isolation signal, the feed pump turbines are tripped and the MFW control valves and the feed pump discharge valves close.
Plant Heating Steam System	**No**	**Yes**	**No**	FSAR only lists as a shared system. No further information available. However, this is probably part of the auxiliary steam system or is feed steam from that system.
STRUCTURES				
Containment		**No**	**N/A**	Each unit has its own containment building.
Turbine Building				The turbine room is a room in the Auxiliary Building.
Service Building	**No**	**Yes**		
Auxiliary Building	**No**	**Yes**		The auxiliary building is basically a five-level compartmented structure

Table C.2 continued

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
				containing the auxiliary nuclear equipment for both units. All equipment handling radioactive fluids are located on the lower four levels of the auxiliary building. The fourth level also houses the two control rooms and the ventilation equipment.
Fuel Handling Area	**No**	**Yes**		See new and spent fuel pools. The Fuel Handling Area is in the Auxiliary Building.
Screenhouse		**Yes**		The screenhouse is located more than 300 feet away from the closest safe shutdown equipment in the yard. A 10-inch interior loop header for the fire protection system is located in the turbine and screenhouse buildings. This interior header is connected to the outdoor loop header by valved connections routed through the service building, auxiliary building and the yard. The Essential Service Water Pumps take suction from a separate section of the screenhouse which cannot be isolated from the lake. Lake water is supplied to the screenhouse forebay by three 16 foot diameter pipes which terminate approximately 2250 feet from shore.
Lake Intake Structures	**No**	**Yes**		Water is drawn from three submerged intake structures in the lake, located ~2,250 feet from the shoreline, and is piped through three parallel lines to the screen house. The screen house, common to both units, contains the circulating water pumps and valves, traveling water screens, essential service water pumps, and associated equipment. De-icing features permit a portion of the warm circulating water discharge from either unit to be redirected to the intake structures during winter months. There are seven circulating water pumps - three for Unit No. 1, and four for Unit No. 2. Each pump takes suction from its respective pump well in the screen house. The water is pumped via the intake tunnels to the main condensers from where it returns to the lake via the discharge tunnels and submerged discharge pipes approximately 1150 feet from the shoreline.
ELECTRICAL				All plant electrical systems are designed to ensure maximum operating

Table C.2 continued

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
				efficiency and reliability under all conditions. The plant is connected to seven independent external circuits, (six via the 345 kV switchyard and one via the 765 kV switchyard). The switchyards are interconnected and all switchyard equipment is protected from lightning.
Emergency Diesel Generators	**Yes**	**No/Yes**	**No**	The emergency power source for each unit consists of two diesel generators. There are two diesel fuel oil storage tanks on site, physically separated from each other. The piping is arranged so that each storage tank supplies fuel to one emergency diesel generator in each unit. Each storage tank contains enough fuel oil to run one emergency diesel generator at full load continuously for greater than seven days.
Electric power system – 4160 VAC	**Yes**			The 4160 volt system for Unit 1 is divided into eight bus sections (1A, 1B, 1C, 1D and T11A, T11B, T11C and T11D). Buses 1A and 1B are normally supplied either from transformer TR1AB when the main generator is in operation or from transformer TR101AB when the main generator is not in operation. Buses 1C and 1D are supplied in a similar manner, from either transformer TR1CD or transformer TR101CD. Upon unit trip, 4160 volt bus 1A, 1B, 1C, and 1D automatically transfer from their normal auxiliary source to the preferred offsite power source. Buses T11A, T11B, T11C and T11D are supplied from buses 1A, 1B, 1C and 1D, respectively, or by diesel generators 1AB or 1CD during a loss of power incident. T11A, T11B, T11C and T11D are also directly alignable to the alternate source of off-site power, the 69/4.16 kV transformer. An identical bus arrangement (2A, 2B, 2C, 2D and T21A, T21B, T21C and T21D) is provided for Unit 2.
Electric power system – 600 VAC	**Yes**			The 600 volt system for Unit 1 is divided into six bus sections. Four of these sections (11A, 11B, 11C and 11D) are fed from 4160 volt buses T11A, T11B, T11C and T11D, respectively, each through a 2000 kVA, 4160/600volt transformer. Two 600 volt bus sections (11BMC and 11CMC), are fed from 4160 volt buses 1B and 1C, respectively, each through a 1500/2000 kVA, 4000/600 volt transformer. An identical bus arrangement (21A, 2lB, 21C, 21D and 21BMC and 21CMC) is provided for Unit 2.
Electric power system – 480 VAC	**No (?)**			The 480 volt systems for each unit are divided into two bus

Table C.2 continued

Cook	In IPE	Shared System	Cross -Tie	Comments (W)
				sections (11PHA, 11PHC in Unit 1 and 21PHA, 21PHC in Unit 2) and are used to provide power to the pressurizer heaters. Buses 11PHA and 11PHC are fed from two 4160/480V, 1000 kVA transformers (TR11PHA and TR11PHC, respectively). These transformers are fed from 4160 volt buses T11A and T11D respectively. Buses 21PHA and 21PHC are fed from two 4160/480 volt, 1000 kVA transformers (TR21PHA and TR21PHC, respectively). These transformers are fed from 4160 volt buses T21A and T21D respectively.
Electric power system – 120 VAC	**Yes**			The 120 volt ac vital instrument bus system consists of four separate vital buses which are supplied by four independent 7.5 kVA, single phase static inverters. The Unit 1 channel III bus supplies a Unit 2 source range neutron flux monitor N-23 on a local shutdown panel and the channel III Unit 2 bus supplies power to the Unit 1 N-23 monitor. This provides indication of unit reactor shutdown for emergency remote shutdown from an alternate control/monitoring station outside of the associated control room.
Electric power system – 250 VDC	**Yes**			The 250 volt AB & CD batteries supply dc power for operation of turbine generator emergency auxiliaries, switchgear, annunciators, vital bus inverters, motor operated valves and emergency lighting. The battery system shown in Figure 8.3-2 for each unit consists of two separately located sets of 116 lead acid cells. Each AB &CD battery has its own active normal charger and a wired standby charger. Each charger is connected to a different 600 volt ac bus. Transfer from one charger to the other is manual. No automatic transfer between chargers is provided. Two batteries and their chargers are located in each unit.

Table C.3 Systems Credited in the PRA for Oconee 1, 2, and 3

Oconee 1, 2, and 3	**In IPE**	**Shared System**	**Cross-Tie**	**Comments** (B+W)
MECHANICAL SYSTEMS				
Engineered Safety Features Systems				
Primary Pressure Control	**Yes**			
Containment Isolation	**Yes**			
Reactor Building Spray	**Yes**			
Emergency Core Cooling System	**Yes**			
Reactor Building Cooling System	**Yes**			
Auxiliary Systems				
Chemical Addition and Sampling System		**1, 2**		Chemical addition and sampling operations are required to change and monitor the concentration of various chemicals in the RCS and auxiliary systems. The chemical addition and sampling system is designed to add boric acid to the spent fuel pool, borated water storage tank, letdown storage tank, and core flooding tanks. Lithium hydroxide is added for pH control and hydrazine is added for oxygen control. The sampling system has separate sampling stations for reactor coolant and steam generator sampling for each of the three units. Two auxiliary systems sampling stations are provided, one for Oconee 1 and 2 and one for Oconee 3. The chemical addition and sampling system performs no emergency functions.
Condenser Circulating Water (CCW) System	**Yes**	**1, 2, 3 not on list of shared systems**		The condenser circulating water system provides for cooling of the condensers during normal operation. The system also serves as the ultimate heat sink for decay heat removal during cooldown. The system is also the suction source for other service water

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	Comments (B+W)
Condenser Circulating Water (CCW) System	**Yes**	**1, 2, 3 not on list of shared systems**		systems, including the high-and low-pressure service water systems, the auxiliary service water system, and the safe shutdown facility (SSF) auxiliary service water system. Each unit has four condenser circulating water pumps supplying water via two 11 ft. conduits into a common condenser intake header under the turbine building floor. (Thus, there are 12 pumps located at the intake structure.) The discharge from the condenser is returned to the Keowee River arm of Lake Keowee. The CCW headers can be connected between Oconee 1, 2, and 3 to allow flow from either or all units as required.
Low Pressure Service Water (LPSW) System	**Yes**	**1, 2**		The low pressure service water (LPSW) system provides cooling water for normal and emergency services throughout the station. Safety related functions served by this system are • Reactor building cooling units, • Decay heat removal coolers • High-pressure injection pump motor bearing cooliers • Motor-driven emergency feedwater pump motor air coolers • Turbine-driven emergency feedwater pump cooling water jacket. Ononee 1 and 2 share three LPSW pumps. The LPSW pumps and the HPSW pumps take suction from the 42-in crossover line between the condenser inlet headers; two LPSW pumps are supplied by one suction line and the other pump is supplied by the other suction line. The HPSW system is connected

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	**Comments** (B+W)
				to LPSW at the LPSW pump discharge to provide emergency backup. For Oconee 3, each of the two LPSW pumps take their suction from the same 42-in crossover line. These pumps provide cooling water via separate supply lines to the ESF equipment in the reactor building and the auxiliary building similar to Oconee 1 and 2. During normal operation, the cooling requirements are supplied by operating one LPSW pump per unit. The LPSW requirement following a LOCA can also be supplied by one pump per unit. The spare pump is started by the ESFAS to provide redundancy for single failure criteria.
High Pressure Service Water (HPSW) System	**Yes**	**1, 2, 3**		The high pressure service water system provides a source of water for fire protection throughout the Oconee station. Two full size and one reduced size high pressure service water pumps supply the high pressure system. A 100,000 gallon elevated water storage tank provides inventory for a backup supply of water. The reduced size pump will normally operate to keep pressure on the fire headers. In the event of a fire, one full size pump provides adequate capacity for automatically maintaining the elevated water storage tank inventory. The second full size pump is an installed spare. The HPSW pumps take suction from the condenser circulating water system. The HPSW and LPSW pump suctions are connected to the 42-in cross-connection between the condenser circulating water inlet headers for the three units. Manual isolation valves are provided so that service water may be supplied from any or all of the inlet

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	**Comments** (B+W)
				headers. Water is supplied to the HPSW pumps from the CCW system piping. Intake for this water is through the 12 pumps located at the intake structure. Intake for HPSW pump A is at the CCW cross-connect heater in Oconee 1 and for HPSW pump B and the jockey pump at Oconee 2.
Auxiliary Service Water (ASW) System		**1, 2, 3 Not listed in SAR as shared system**		The auxiliary service water system is designed to remove decay heat from all three units simultaneously, assuming the concurrent loss of each unit's main feedwater, emergency feedwater, and LPI Systems. The system also serves as a backup source of cooling water for the high-pressure injection pump motor coolers. The auxiliary service water system uses the plant condenser cooling water intake and discharge conduits as a source of raw cooling water. These conduits are interconnected by crossovers and unwatering lines. An auxiliary service water pump located in the auxiliary building takes its suction from the Oconee 2 intake conduit and discharges into the steam generators of each unit via separate lines into the emergency feedwater headers.
Compressed Air	**Yes**			
Instrument and Breathing Air Systems	**Same as compres sed air?**	**1, 2, 3 Not listed in SAR as shared system**	**Yes**	The instrument and breathing air systems are designed to provide clean, dry, oil free instrument air to all air operated instrumentation and valves. Instrument air (IA) system consists of one primary IA compressor and three backup compressors. The IA system is shared by all three Oconee Units; therefore, the IA system is required to operate continuously.

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	**Comments** (B+W)
				Normal operation is for the primary IA compressor to supply all IA demands. An auxiliary instrument air (AIA) system provides a backup auxiliary source of instrument air to key plant components. This system is composed of three (one per unit) compressors. Separate distribution headers and supply lines are provided to these key components to ensure AIA availability. Although the AIA System may be available, it is not required for performing or supporting any operation. The Unit 1 and 2 Breathing Air System and the Unit 3 Breathing Air System each consist of one primary and one backup compressor package. The breathing air systems are cross connected in such a way that any of the compressors can supply either of the Units' breathing air needs.
Fire Protection		**1, 2, 3 Not listed in SAR as shared system**		The water supply for the fire protection is an underground fire loop around the perimeter of the plant site. Connections from this header to the units are redundant. Two 6000 gal/min and one 500 gal/min (jockey) high-pressure service water pumps supply the HPSW system. The 500 gal/min pump will normally operate to keep pressure on the fire headers. In the event of a fire, one full size pump provides adequate capacity for fire protection service. The second full size pump is considered to be a spare. Since both HPSW pumps are powered directly from the 4160 V Buses which are interconnected between Oconee 1, 2, and 3 and to the emergency power from Keowee Hydro, adequate backup power is provided.

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	Comments (B+W)
Spent Fuel Pool		**1, 2**		The spent fuel pool common to Oconee Units 1 and 2 is an integral part of the Oconee 1 and 2 Auxiliary Buildings.
Spent Fuel Pool Cooling System		**1, 2**		For the Units 1 and 2 spent fuel cooling system, the design basis normal heat load assumes that Units 1 and 2 are refueled consecutively. In addition to the primary function of decay heat removal, the system provides for purification of the spent fuel pool water, the fuel transfer canal water, and the contents of the borated water storage tank, in order to remove fission and corrosion products and to maintain water clarity for fuel handling operations. The system also provides inventory makeup for the fuel transfer canal and the incore instrument handling tank.
New Fuel Storage Area		**1, 2**		New fuel will normally be stored in the spent fuel pool serving the respective unit. New fuel may also be stored in the fuel transfer canal.
Heating, Ventilation, and Air Conditioning	**Yes**			
Turbine Building Ventilation System		**1, 2, 3**		The turbine building is ventilated using 100% outside air. Air is supplied through wall openings and is exhausted by fans mounted in the roof and along a wall. There are 12 roof mounted exhaust fans. Eighteen additional fans are located along the west wall. Each of the 30 fans are independently operated so that all or a portion of the fans can run as needed. The system is in continuous operation during normal plant operation.
Control Room Ventilation System		**1, 2**		The control room ventilation and air conditioning

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	Comments (B+W)
				systems are designed to maintain the environment in the control are which is composed of the control room, cable room and electrical equipment rooms within acceptable limits. The control room for Oconee 1 and 2 is shared for the operation of both units. The control room is primarily served by two large air handling units. The units are 100% capacity and only one is required to operate at a time. Cooling to the cable rooms and equipment rooms is provided by a total of four air handling units. The Unit 3 control area is comprised of the control room, cable room and electrical equipment room. These areas are served by six air handling units. Two 100% capacity air handling units serve each room. The chilled water for the air handling units is supplied from the Plant WC Chilled Water System, which is capable of supplying sufficient chilled water for all necessary systems with one of two chillers in service.
Spent Fuel Pool Area Ventilation System		**1, 2, 3 Not listed in list of shared systems**		The spent fuel pool area ventilation system is designed to maintain a suitable environment for the operation, maintenance and testing of equipment and also for personnel access. Ventilation air for the spent fuel pool area is supplied by a single air handling unit. Prior to handling fuel in the spent fuel pool area, the spent fuel pool ventilation system must be made operable.
Auxiliary Building Ventilation System		**1, 2 Unit 3 not listed as**		The auxiliary building ventilation system serves all areas of the Auxiliary Building with the exception of the control room area and the penetration rooms.

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	Comments (B+W)
		sharing aux building vent system?		There are six main supply fans, each required for normal plant operation. Auxiliary Building air is exhausted from the building, via exhaust duct and exhaust fans, through three unit vent stacks.
Component Cooling (CC) System	**Yes**			The component cooling system is designed to provide cooling water for various components in the Reactor Building. Oconee 1 and 2 each have a single component cooler with a shared common spare. Oconee 3 has 2 coolers. The coolers reject the heat load to the low-pressure service water system. During normal operation, one component cooling pump and one component cooler recirculate and cool water to accommodate the system heat loads for each reactor unit. The component cooling system serves no emergency functions and the only consideration following a LOCA is the operation of the isolation valves.
Liquid Waste Disposal		**1, 2, 3**		
Gaseous Waste Disposal		**1, 2**		
Solid Waste Disposal		**1, 2, 3**		
Area Radiation Monitoring		**1, 2**		
Process Radiation Monitoring		**1, 2**		
Steam and Power Conversion Systems				
Emergency Feedwater	**Yes**			
Auxiliary Steam System		**1, 2, 3**		
Coolant Treatment System		**1, 2, 3**		The coolant treatment system was originally designed and installed to both store reactor coolant bleed and to treat reactor coolant bleed for recycling. Since the boron recycling portion of the original coolant treatment system never functioned

Table C.3 continued

Oconee 1, 2, and 3	In IPE	Shared System	Cross-Tie	Comments (B+W)
				properly, the coolant storage portion is the only part of the system still in use at Oconee.
Recirculated Cooling Water (RCW) System		**1, 2, 3**	**Yes**	The recirculated cooling water system is a closed loop system to supply corrosion inhibited cooling water to various components outside the Reactor Building. This system has no direct safety-related functions and does not penetrate the Reactor Building. This system consists of two parallel loops that are normally isolated from each other. One loop supplies cooling for shared stations loads, Unit 1 and 2 loads and secondary loads on Unit 3. The other loop supplies cooling for Unit 3 primary loads. The number of RCW pumps and RCW heat exchangers in operation varies depending on the spent fuel heat load and lake water temperature. The isolation valves that normally separate the two parallel loops can be opened, however; it is not a necessary configuration.
Power Conversion System	**Yes**			
STRUCTURES				
Standby Shutdown Facility	**Yes**			The standby shutdown facility (SSF) is designed as a standby system for use under extreme emergency conditions. The SSF will be placed into operation to mitigate the consequences of the following events: • Flooding • Fire • Sabotage • Station blackout
ELECTRICAL (ac and dc power systems)	**Yes**			

Table C.3 continued

Oconee 1, 2, and 3	**In IPE**	**Shared System**	**Cross-Tie**	**Comments** (B+W)
Electric power system – 4160 VAC	**Yes**	**1, 2, 3**		
480-V MCC's feeding to the common systems load and lighting	**Yes**	**1, 2, 3**		
Electric power system – 120 VAC	**Yes**	**1, 2, 3**		
Electric power system – 125/250 VDC	**Yes**	**1, 2, 3**		

Table C.4 Systems Credited in the PRA for Browns Ferry 1, 2, and 3

Browns Ferry 1, 2 & 3	In Multi-Unit PRA	Shared System	Cross -Tie	Comments
MECHANICAL SYSTEMS				
Auxiliary Systems				
Auxiliary Boiler System	**No**	**YES**		
Residual Heat Removal (RHR) Service Water System	**YES**	**YES**		This system serves all of the units at the plant. The RHRSW system is composed of 4 pairs of pumps assigned to the RHR systems of the 3 units. An additional set of 4 pumps co-located with the RHRSW pumps is assigned to the EECW system. There are also 4 swing pumps nominally assigned to the RHRSW system. Each pair of RHRSW pumps feeds one independent RHR service water header, which, in turn, feeds one RHR heat exchanger on each unit. Four of the RHRSW pumps can be aligned for alternative service to supply the two EECW headers. The design criterion states that two RHRSW pumps and two RHR heat exchangers are required for heat removal. The RHRSW pumps are addressed individually in the support system event tree.
Raw Cooling Water System	**YES**	**YES**		The raw cooling water system serves all 3 units. The suction headers for Units 1 and 2 are interconnected. Nominally, 3 pumps are assigned to each unit with one shared spare. The suction header for Unit 3 is independent. 7 pumps serve Units 1 and 2, and an additional 5 pumps serve Unit 3.
Raw Service Water System	**No**	**YES**		

Table C.4 continued

Browns Ferry 1, 2 & 3	In Multi-Unit PRA	Shared System	Cross -Tie	Comments
High Pressure Fire Protection System	**YES**	**YES**		The part of interest in the PRA is the high-pressure water subsystem; specifically, the diesel-driven fire pump. Its role in mitigating severe scenarios such as a complete loss of ac power is to provide vessel injection or drywell spray. The plant has only one diesel fire pump.
Potable Water System	**No**	**YES**		
Reactor Building and Control Bay Ventilation and Cooling Systems	**YES**	**YES**		Five separate air conditioning systems serve five separate areas of the control building. One systems serves the Units 1 and 2 main control room; a second system serves the Units 1 and 2 auxiliary instrument rooms; a third system serves the switchyard relay room common to all three units; a forth system serves the Unit 3 main control room; and the fifth system serves the Unit 3 auxiliary instrument room.
Heating, Ventilation, and Air Conditioning System		**YES**		*I don't know the difference between this system and the reactor building and control bay ventilation and cooling systems covered above.*
Control Air System	**YES**	**YES**		Control air and service air are shared among the 3 units. Each unit has its own drywell control air system for supplying air-operated devices inside the affected drywell. The plant control air (PCA) system consists of 4 compressors connected to a common header that supplies 3 air receivers. The receivers supply 4 dryers, 1 for each unit, with 1 standby dryer that can be used on any unit.
Service Air System	**YES**	**YES**		

Table C.4 continued

Browns Ferry 1, 2 & 3	In Multi-Unit PRA	Shared System	Cross -Tie	Comments
Emergency Equipment Cooling Water (EECW) System	**YES**	**YES**		This system serves all of the units at the plant. Four pumps co-located with the RHRSW pumps in the intake pumping station are assigned to the EECW system. Two pumps are assigned to each of the two EECW system headers. There are also 4 swing pumps nominally assigned to the RHRSW system. The model representing the potential to use RHRSW swing pumps to support the EECW system is different for a single unit PRA vs. multi-operation PRA.
Reactor Building Closed Cooling Water (RBCCW) System	**YES**	**YES**		Each unit has 2 operating RBCCW system pumps. A common pump is shared between Units 1, 2, and 3. The existing PRA model treats that pump as an installed spare supporting Unit 2 operation.
Radioactive Waste Treatment System	**No**	**YES**		
Diesel Generator System	**YES**	**YES**		8 DG units supply power to 8 independent 4160 shutdown boards. Thus, the 8 DGs serve all 3 units; only 6 are required to be available. The limiting condition is the case in which all 3 units are initially at power.
Control Rod Drive Hydraulic System	**YES**	**YES**		Units 1 and 2 each have a dedicated control rod drive pump. Additionally, a common control rod drive hydraulic system pump is shared by Units 1 and 2. There is a swing pump that can be shared between Units 1 and 2. The shared portion of this system is not Class I seismic. Unit 3 has 2 pumps, one is dedicated and the other is standby.
Radiation Monitoring System	**No**	**YES**		
Cranes System	**No**	**YES**		

Table C.4 continued

Browns Ferry 1, 2 & 3	**In Multi-Unit PRA**	**Shared System**	**Cross -Tie**	**Comments**
New Fuel Storage	**No**	**No**	**No**	Each unit has its own new fuel storage
Spent Fuel Pool	**No**	**No**	**No**	Each unit has 3 spent fuel storage pools
Other systems not listed in SER				
Drywell Equipment and Floor Drain Systems	**No**	**YES**		
Plant Communications Systems	**No**	**YES**		
Lighting System	**No**	**YES**		
Hardened Wetwell Vent	**No**	**YES**		
Standby Coolant Supply System	**YES**	**No**	**YES**	The standby coolant supply system provides the capability to crosstie selected portions of the RHR systems at the plant. Specifically, from the point of view of serving Unit 2, RHR pump B or D from Unit 1 can be connected to Unit 2 train A or C; and RHR pumps A and C on Unit 3 can be connected to Unit 2 train B or D. Additional valve manipulation permits RHRSW pump D2 or D1 to inject water to the vessel or provide drywell spray for unit 1 or 2; similarly, the possibility exists for RHRSW pump B2 or B1 to inject water to the vessel or provide drywell spray for Unit 2 or 3. A limiting condition is that cross-ties are unavailable during construction.
Standby Gas Treatment System		**YES**		
Steam and Power Conversion Systems				
Condensate and Demineralized Water System		**YES**		

Table C.4 continued

Browns Ferry 1, 2 & 3	In Multi-Unit PRA	Shared System	Cross -Tie	Comments
Condenser Circulating Water System	**YES**	**YES**	**YES**	The condenser circulating water system consists of 3 circ water pumps per unit. In the normal mode of operation, this system is unitized. Crosstie capability exists, however it is not modeled in the multiunit PRA. The system is modeled as a unit specific system.
STRUCTURES				
Reactor Buildings (secondary containment systems)	**YES**	**YES**		The reactor building is shared among the 3 units and is divided into 3 reactor zones and a common refueling zone. A severe accident at one of the units affects the probability of operator actions associated with reactor building entry for the other units.
Diesel Generator Buildings	**No**	**YES**		
Standby Gas Treatment Building	**No**	**YES**		
Intake Pumping Station	**YES**	**YES**		The key shared system aspect of the pumping station is that RHRSW pumps and EECW pumps (12 total) are located in 4 compartments at the pumping station. Flooding of any of the individual pump rooms has the potential to impact all units in service. Room-to-room flooding at the pumping station is determined to be incredible due to the physical barriers separating the 4 individual rooms.
Turbine Buildings	**YES**	**YES**		This building is shared among units. The impact on PRA models is the flood events and considers the effects of all 3 units in operation.

Table C.4 continued

Browns Ferry 1, 2 & 3	In Multi-Unit PRA	Shared System	Cross -Tie	Comments
Transformer Yard	**YES**	**YES**		
161 kV Switchyard	**YES**	**YES**		The 161 kV lines have common station service transformers.
500 kV Switchyard	**YES**	**YES**		
Radwaste Building	**No**	**YES**		
Control Bay		**YES**		
Spent Fuel Storage Facilities		**YES**		
Gaseous Radwaste System (stack)		**YES**		
Standby ac Power Supply and Distribution		**YES**		
ELECTRICAL AND INSTRUMENTATION & CONTROL				
Electric power system – 4160 VAC	**YES**	**YES**		
Electric power system – 600 VAC		**YES**		
Electric power system – 120 VAC	**YES**	**YES**		
Electric power system – 250 VDC	**YES**	**YES**		Batteries serve all 3 units.