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PRIORITY RANKING OF SAFETY-RELATED SYSTEMS FOR STRUCTURAL ENHANCEMENT ASSESSMENT AT SAVANNAH RIVER SITE

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ABSTRACT

In order to extend the service life of safety related structures and systems in a logical manner, a Structural Enhancement Program was initiated to evaluate the structural integrity of eight (8) systems, namely: Cooling Water System, Emergency Cooling System, Moderator Recovery System, Supplementary Safety System, Water Removal System, Service Raw Water System, Service Clarified Water System, and River Water System. Since the level of importance of each system to reactor operations varies from one system to another, the scope of structural integrity evaluation for each system should be prioritized accordingly.

This paper presents the assessment of system priority for structural evaluation based on a ranking methodology and specifies the level of structural evaluation consistent with the established priority. The effort was undertaken by a five-member panel representing four (4) major disciplines, including: structures, reactor engineering / operations, risk management and materials.

The above systems were divided into a total of thirty-five (35) subsystems. These subsystems were then ranked with six (6) attributes, namely: Safety Classification, Degradation Mechanisms, Difficulty of Replacement, Failure Mode, Radiation Dose to Workers and Consequence of Failure. Each attribute was assigned a set of consequences or events with corresponding weighting scores. The results of the ranking process yielded two groups of subsystems, categorized as Priority I and II subsystems. The level of structural assessment was then formulated accordingly.

The prioritized approach will allow more efficient allocation of resources, so that the Structural Enhancement Program can be implemented in a cost-effective and efficient manner.

INTRODUCTION

This paper describes a methodology to establish the priority ranking of secondary systems for assessing structural integrity. Based on the results of the ranking, the level of structural evaluation which is consistent with the established priority can be defined.

There were eight secondary systems ranked under this program, including: Cooling Water System (CWS), Emergency Cooling System (ECS), Moderator Recovery System (MRS), Supplementary Safety System (SSS), Water Removal System (WRS), Service Water System (SRW), Service Clarified Water System (SCW), and River Water System (RWS).

The priority rar ٦ of the secondary systems was accomplished collectively by a five-member panel. The backgrour. the panel members is presented below:

- Reactor Engineering and Operations
- Risk Analysis
- Structures
- Materials

The ranking process was performed in two phases, as follows:

First Phase	The identification and ranking of attributes used to assess the priority of each subsystem and obtaining weighting factors.
Second Phase	The definition of subsystems for each system, and the scoring of subsystems.

The following six (6) attributes were selected in ranking each subsystem:

- Safety Classification
- Degradation Mechanisms
- Difficulty of Replacement
- Failure Mode
- Radiation Dose to Workers
- Consequence of Failure

The panel ranked the relative importance of these attributes in relation to reactor operations and safety concerns and developed a set of weighting factors for these attributes. Within each attribute, either three or four categories of importance are identified, with a numerical value corresponding to each category. The attribute category and weighting factor are used in the ranking assessment.

Each secondary system was divided into several subsystems. The grouping of subsystems was based on the primary function(s) of a segment of piping and its attached components, such as pumps, valves, expansion joints, etc. A total of thirty-five (35) subsystems were identified in this manner. The distribution of subsystems is shown below:

- CWS: 10 subsystems
- ECS: 4 subsystems
- MRS: 4 subsystems
- RWS: 3 subsystems
- SCW: 4 subsystems
- SRW: 2 subsystems
- SSS: 5 subsystems
- WRS: 3 subsystems

The scoring of a subsystem was achieved by the consensus of the panel members. A subsystem receives a score for each attribute that is determined by the category considered most appropriate for that subsystem. The weighted score for each subsystem is obtained by multiplying the score for each attribute by that attribute's weighting factor, and summing the results. Finally, the weighted scores were used to determine the level of system evaluation to be performed on the subsystems.

RANKING OF ATTRIBUTES

The importance of attribute was defined by categories of probable events or consequences. Such events or consequences were assigned with numerical values to reflect the relative level of importance. Details of the ranking are as follows:

Safety Classification

The attribute, Safety Classification, is related to the classification of structural/mechanical systems as defined in Safety Analysis Report (Reference 1). There are four categories of safety classification pertaining to subsystem structures, with corresponding numerical values of 1, 2, 4 and 8. Details of classification are given below:

SAR Safety Classification	Description	Numerical Value
Safety Class 1 (SC-1)	As defined in the Safety Analysis Report	8
Safety Class SC-2 (SC-2)	As defined in the Safety Analysis Report	4
Safety Class SC-3 (SC-3)	As defined in the Safety Analysis Report	2
Non-Nuclear Safety (NSS)	As defined in the Safety Analysis Report	1

Degradation Mechanisms

The attribute, Degradation Mechanisms, indicates the consequences of degradation-mechanism attacks on a subsystem (Reference 2). There are three categories of consequence postulated for Degradation Mechanisms, with corresponding numerical values of 1, 2, and 4, respectively. The classification of Degradation Mechanisms is given below:

Condition of Degradation-Mechanism Attacks	Description	Numerical value
Severe	• Located in high flow areas or high radiation areas, or • Containing corrosive liquids or stagnant water, or • Experiencing extreme temperature variations and/or severe vibrations, or • Has long history of corrosion problems, or • Buried underground.	4
Moderate	• Operating within normal operating conditions, and • Has experienced minor environmental related problems.	2
Low	• Not sensitive to environmental attacks.	1

Difficulty of Replacement

The attribute, Difficulty of Replacement, reflects the cost and the level of difficulty related to the replacement of subsystem piping and/or equipment. The replacement effort was categorized into three categories, with corresponding numerical values of 1, 2, and 4, respectively, as presented below.

Difficulty of Replacement	Description	Numerical value
Extremely difficult to replace	• Located in inaccessible areas, or • Original Equipment Manufacturer (OEM) no longer produces replacements or parts, or • Located in high radiation areas, or • Requires intense ISI, or • Very costly.	4
Difficult, but replaceable	• Located in very cramped areas, or • Located in medium or low radiation areas, and • Requires normal ISI.	2
Easy to replace	• Has easy access to repair areas, and • Has good working environments, and • Outside of Radiation Zone (RZ)	1

Failure Mode

The attribute, Failure Mode, indicates the rate of detectable structural failure that might occur in a subsystem or a component during the life of a plant. Three categories of "failure rate" were postulated for "Failure Mode", with corresponding numerical values of 1, 2, and 4, respectively. The classification of Failure Mode is given below:

Failure Mode	Description	Numerical value
Rapid Failure	• Component would fail or sever from subsystem rapidly without warning.	4
Fail at moderate rate	• Failure would occur at a moderate to low rate, and • Would exhibit ductile failure, and • Would develop leaks.	2
Fail at low rate or no failure	• Failure would occur at extremely low rate to provide ample warning.	1

Radiation Dose to Workers

The attribute, Radiation Dose to Workers, indicates the radiation dosage which would be received by person(s) working in an area where replacement or repair for a subsystem is taking place. Three categories of dosage level were postulated for "Radiation Dose to Workers", with corresponding numerical values of 1, 2, and 4, respectively. The classification of Radiation Dose to Workers is given below:

Radiation Dose to Workers	Description	Numerical value
High	• Workers would be subject to high level of radiation.	4
Low to Medium	• Workers would be subject to low to medium level of radiation.	2
None	• Essentially no radiation exposure potential	1

Consequence of Failure

The attribute, Consequence of Failure, reflects the potential impact of structural failure of a subsystem to plant operations and safety of the general public. Three categories of impact were postulated for "Consequence of Failure", with corresponding numerical values of 1, 2, and 4, respectively. The classification of "Consequence of Failure" is given below:

Consequence of Failure	Description	Numerical value
Serious	• Release of radioactive materials, or • Has severe impact to the environment, or • Pose health threat to the general public.	4
Moderate	• Cause plant to shut down, and • Radioactivity can be controlled.	2
None	• Pose no impact to the environment, and • Pose no threat to the general public.	1

WEIGHTING FACTORS FOR THE ATTRIBUTES

The five-member panel ranked the relative importance of the attributes, in the range from 1 to 10, to obtain weighting factors. In this process, the rankings of three members from the materials and structures group were averaged to present the group ranking. The results are presented below.

	Safety Classification	Degradation Mechanisms	Difficulty of Replacement	Failure Mode	Radiation Dose to Workers	Consequence of Failure
Materials & Structures	10	3	6	4	5	8
Reactor Engineering	6	2	1	8	4	10
Risk Analysis	5	10	5	8	3	10
Subtotal of scores	21	15	12	20	12	28
Weighting Factor	19 %	14 %	11 %	19 %	11 %	26 %

The attribute " Consequence of Failure " received the highest weight of 26%; the lowest weight of 11% belongs to both "Radiation Dose to Workers" and "Difficulty of Replacement".

DEFINITION AND RANKING OF SUBSYSTEMS

Cooling Water System

The purpose of the Cooling Water System (CWS) is to provide coolant to the process water heat exchangers (Reference 1). The CWS also provides cooling to a variety of other thermal loads, including the shield heat exchangers, process water pump systems, and diesel generators. In addition, the CWS provides two sources of water to the Emergency Cooling System (ECS). The CWS was divided into 10 subsystems and designated as CWS-1 thru CWS-10.

Supplementary Safety System

The purpose of the Supplementary Safety System (SSS) is to provide a backup to the safety rods and control rods to shutdown the reactor and maintain a subcritical condition (Reference 1). Safety analyses assume the SSS to be the only operable shutdown mechanism in the event of an earthquake. The SSS was divided into 5 subsystems and designated as SSS-1 thru SSS-5.

Emergency Cooling System

The Emergency Cooling System (ECS) is a standby accident mitigation system that removes heat to allow maintaining a coolable core geometry in the event of an emergency (Reference 1). This is accomplished by injecting light water directly into four of the six primary coolant loops. The ECS is designed to mitigate the effects of a Loss of Coolant Accident (LOCA) and a Loss of Pumping Accident (LOPA).The ECS was divided into 5 subsystems and designated as ECS-1 thru ECS-4.

Moderator Recovery System

The purpose of the Moderator Recovery System (MRS) is to reclaim moderator inadvertently released from the primary coolant system. For relatively small moderator releases, the MRS will be used in lieu of the emergency cooling system and will prevent release of the moderator to the environment (Reference 1). The MRS was divided into 4 subsystems and designated as MRS-1 thru MRS-4.

River Water System

The purpose of the River Water System (RWS) is to provide a source of water to the water basin for cooling of various systems and components. Water can be drawn from either the Savannah River or Par

Pond. The system provides a backup source of cooling water to the emergency cooling system . The RWS is divided into 3 subsystems and designated as RWS-1 thru RWS-3.

Water Removal and Storage System

The primary purpose of the WRS system is to remove water associated with accidents, such as Loss of Coolant Accidents (LOCA), Loss of Pumping Accidents (LOPA), and reactor room spray initiation, and store the water to minimize releases to the environment. The secondary purpose is to remove leakage that occurs during normal operation and after a Design Basis Earthquake (DBE) (Reference 1). The WRS was divided into 3 subsystems and designated as WRS-1 thru WRS-3.

Service Raw Water System

The SRW supplies water from the water basin for auxiliary equipment cooling, such as the chilled water refrigerant condensers and the process water purification system, and as a backup supply to the process room spray (PRS) system (Reference 1). The SRW was divided into 2 subsystems and designated as SRW-1 and SRW-2.

Service Clarified Water System

The water in the SCW has a pH value of 6.7 , and chlorine residual of 1 ppm. This water is used at hose stations, seal pots, safety showers, as primary source of coolant for the discharged reactor fuel and target assemblies, and for filling and makeup to the chilled water system (Reference 1). The SCW was divided into 4 subsystems and designated as SCW-1 thru SCW-4.

PRIORITY SCORING OF SUBSYSTEMS

Each attribute of a subsystem was evaluated based on the information contained in the SAR, historical data, and engineering judgments; the score of the attribute was assigned based on general consensus of the panel. The weighted scores of subsystems are presented in Table 1. The results of the normalized weighted ranking scores are shown in Figure 1.

The scores will be used to guide the system evaluation in several regards. First, the priorities established will help direct the allocation of available resources to the areas most needing them. Second, the relative importance of a system or subsystem will determine the level of effort used to evaluate that system or subsystem. Obviously, a system with relatively low importance would not warrant detailed stress or fracture analyses.

EVALUATION OF STRUCTURAL INTEGRITY

As discussed in the previous section, the level of evaluation for each subsystem depends on its priority ranking score, which indicates the relative importance of that subsystem in relation to other subsystems. From Figure 1, subsystems, which lie at or above the weighted ranking score of 50, are classified as Priority I subsystems, as shown below:

- All ECS subsystems
- CWS-1 through CWS-5
- SSS-1 through SSS-4
- All WRS subsystems
- MRS-1

The remaining subsystems with a weighted score of less than 50, defined as Priority II subsystems, are as follows:

- MRS-2 through MRS-4
- CWS-6 through CWS-10
- SSS-5

- All RWS subsystems
- All SRW subsystems
- All SCW subsystems

It should be noted that the dividing line of weighted score of 50 is not rigid. Therefore, Priority I subsystems that score close to 50 will receive less evaluation effort than subsystems with higher scores. Similarly, Priority II subsystems that score close to 50 will likely receive more attention than subsystems with lower scores.

Evaluation of Priority I Subsystems

The following elements for evaluation shall be considered for the Priority I subsystems:

(1) Review of Design-Related Documents, such as SAR commitments, design specifications, stress analysis report(s), fracture analysis report(s), fabrication records, material test reports ,etc.
(2) Review of Operating Documents, in-service-inspection procedures and acceptance criteria.
(3) Review of leak detection capability and sensitivity
(4) Perform stress analysis (if none exists)
(5) Perform fracture mechanics analysis to determine critical flaw sizes (if none exists)
(6) Identify and/or develop material properties database for prototypic (vintage) materials
(7) Review means of detecting failure and related procedural requirements; identify failure consequences and probability of failures
(8) Perform evaluation on material and fluid compatibility
(9) Review walkdown reports of representative portions of system, if available.

Evaluation of Priority II Subsystems

The following elements for evaluation shall be considered for the Priority II subsystems:

(1) Review of Design-Related Documents, such as SAR commitments, design specifications, stress analysis report(s), fracture analysis report(s), fabrication records, material test reports, etc.
(2) Review of Operating Documents and In-Service-Inspection procedures and criteria.
(3) Review of existing leak detection system.
(4) Perform evaluation on material and fluid compatibility

CONCLUDING REMARKS

The ranking of RSEP system priority has been accomplished through a systematic process. By choosing ranking attributes and subsystems in a realistic and cohesive manner, the priority of the thirty-five (35) subsystems are grouped into two (2) major categories. Namely: Priority I and II subsystems.

The structural evaluation requirements, established for the Priority I and II subsystems, provide the basis to define an appropriate workscope for individual subsystems. In certain cases, the type and extent of analyses performed will vary for different components within a given importance level. For example, pump and valve casings typically have very low operating stresses since a relatively thick, rigid structure is needed to meet functional requirements. Therefore, a pump casing stress analysis would not be needed, although the adjacent piping might have high stresses that need to be assessed. This priority ranking methodology will allow management to make informed decisions on resource allocations and scheduling milestones for evaluating each system, down to the subsystem and component level of detail.

REFERENCES

1. WSRC-SA-10003, *Savannah River Site Production Reactor Safety Analysis Report, K Production Reactor (U), Amendment 1,* July 1991.

2. WSRC-TR-90-318, *Corrosion Processes in Reactor Systems,* September 1990.

ACKNOWLEDGMENTS

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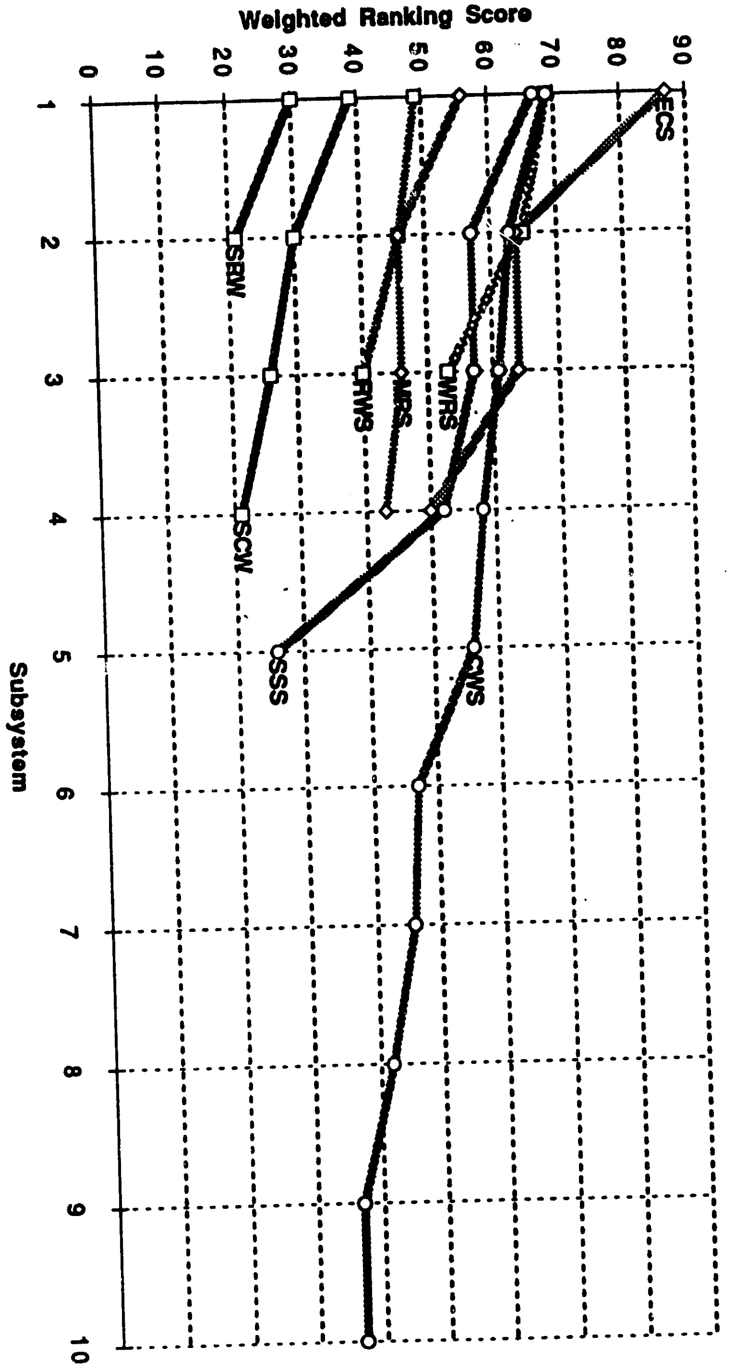
Table 1

Weighted Ranking Scores

SUBSYSTEM	SAFETY FUNCTION	DEGRADA-TION MECHANISMS.	DIFFICULTY OF REPLACE-MENT	FAILURE MODE	RADIATION DOSE TO WORKERS	CONSEQUEN-CE OF FAILURE	WEIGHTED SCORE	NORMALIZED WEIGHTED SCORE
CWS-1	0.76	0.56	0.44	0.38	0.11	1.04	3.29	69
CWS-2	0.76	0.28	0.44	0.38	0.11	1.04	3.01	63
CWS-3	0.76	0.28	0.22	0.38	0.22	1.04	2.9	61
CWS-4	0.76	0.14	0.22	0.38	0.22	1.04	2.76	58
CWS-5	0.76	0.28	0.11	0.38	0.11	1.04	2.68	56
CWS-6	0.76	0.28	0.44	0.38	0.11	0.26	2.23	47
CWS-7	0.76	0.56	0.11	0.38	0.11	0.26	2.18	46
CWS-8	0.76	0.14	0.11	0.38	0.11	0.52	2.02	42
CWS-9	0.76	0.14	0.11	0.38	0.11	0.26	1.76	37
CWS-10	0.76	0.14	0.11	0.38	0.11	0.26	1.76	37
SSS-1	1.52	0.28	0.22	0.19	0.44	0.52	3.17	67
SSS-2	0.76	0.56	0.44	0.19	0.22	0.52	2.69	57
SSS-3	0.76	0.56	0.22	0.19	0.44	0.52	2.69	57
SSS-4	0.76	0.56	0.22	0.19	0.22	0.52	2.47	52
SSS-5	0.19	0.14	0.22	0.19	0.22	0.26	1.22	26
MRS-1	0.76	0.56	0.22	0.38	0.22	0.52	2.66	56
MRS-2	0.76	0.28	0.22	0.19	0.22	0.52	2.19	46
MRS-3	0.76	0.28	0.22	0.19	0.22	0.52	2.19	46
MRS-4	0.76	0.14	0.22	0.19	0.22	0.52	2.05	43
RWS-1	0.19	0.56	0.44	0.76	0.11	0.26	2.32	49
RWS-2	0.19	0.56	0.11	0.19	0.11	1.04	2.2	46
RWS-3	0.19	0.14	0.44	0.76	0.11	0.26	1.9	40
ECS-1	1.52	0.56	0.22	0.38	0.44	1.04	4.16	87
ECS-2	0.76	0.56	0.11	0.38	0.22	1.04	3.07	64
ECS-3	0.76	0.56	0.11	0.38	0.22	1.04	3.07	64
ECS-4	0.76	0.56	0.22	0.38	0.22	0.26	2.4	50
WRS-1	0.76	0.28	0.22	0.76	0.22	1.04	3.28	69
WRS-2	0.76	0.56	0.44	0.19	0.11	1.04	3.1	65
WRS-3	0.19	0.56	0.44	0.19	0.11	1.04	2.53	53
SRW-1	0.19	0.56	0.11	0.19	0.11	0.26	1.42	30
SRW-2	0.19	0.14	0.11	0.19	0.11	0.26	1	21
SCW-1	0.19	0.56	0.44	0.19	0.22	0.26	1.86	39
SCW-2	0.19	0.56	0.11	0.19	0.11	0.26	1.42	30
SCW-3	0.19	0.14	0.22	0.19	0.22	0.26	1.22	26
SCW-4	0.19	0.14	0.11	0.19	0.11	0.26	1	21

Figure 1

Weighted Ranking Scores of Secondary Systems



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