BORATED WATER STORAGE TANK

LICENSE RENEWAL EVALUATION REPORT

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ABBREVIATIONS

ANO-1	- Arkansas Nuclear Power Plant Unit 1
ARDM	- Age-Related Degradation Mechanism
ARDUTLR	- Age-Related Degradation Unique to License Renewal
B&W	- Babcock & Wilcox
B&WOG	- B&W Owners Group
BWST	- Borated Water Storage Tank
CASS	- Cast Austenitic Stainless Steel
CR-3	- Crystal River Nuclear Power Plant Unit 3
CS	- Carbon Steel
DB-1	- Davis-Besse Nuclear Power Plant Unit 1
DBE	- Design Basis Event
DHRS	- Decay Heat Removal System
ECCS	- Emergency Core Cooling System
FSAR	- Final Safety Analysis Report
GLRP	- Generic License Renewal Program
GPM	- Gallons per minute
HAS	- High Alloy Steel
HPI	- High Pressure Injection
IGA	- Intergranular Attack
IPA	- Integrated Plant Assessment
ITLR	- Important to License Renewal
LAS	- Low Alloy Steel
LCO	- Limiting Condition of Operation
LER	- License Event Report
LOCA	- Loss-Of-Coolant-Accident
LOFW	- Loss-Of-Feedwater
LPI	- Low Pressure Injection
MIC	- Microbiologically Influenced Corrosion
NPRDS	- Nuclear Plant Reliability Data System
ONS-1,2&3	- Oconee Nuclear Power Plant Units 1, 2 & 3
PPM	- Parts per Million
PSI	- Pounds per Square Inch
PWR	- Pressurized Water Reactor
RB	- Reactor Building
RC	- Reactor Coolant
RCS	- Reactor Coolant System
SCC	- Stress Corrosion Cracking
SS	- Stainless Steel
TMI-1	- Three Mile Island Nuclear Power Plant Unit 1

1.0 Introduction

1.1 Scope

This report describes the technical evaluation of the effects of age-related degradation of the Borated Water Storage Tanks (BWST) of B&W-designed nuclear power plants. This report is one of a series of reports developed through the B&W Owners Group (B&WOG) Generic License Renewal Program (GLRP) to be used in support of individual license renewal applications by the B&WOG member utilities. The purpose of this report is to determine what age-management measures, if any, are required to allow continued safe operation of the BWST over the extended operating period associated with license renewal.

The B&WOG has developed an Integrated Plant Assessment (IPA) that governs Component Evaluation for the B&WOG GLRP program. The B&WOG Component Evaluation process determines the type of component aging evaluation to be performed based on the component's Important to License Renewal (ITLR) function. The approach discriminates between component functions for which it is appropriate to consider potential Age-Related Degradation Mechanisms (ARDMs) and those for which specific knowledge of ARDMs is not necessary to maintain safety over the extended operating period. The BWST is classified as a long-lived passive component. It's failure could cause a system functional failure; therefore, under the B&WOG IPA methodology, an ARDM assessment of the BWST is required.

This report covers the BWST shell, connecting nozzles, studs, bolts, heater sheaths and manways. Piping, valves, or similar components attached to the BWST are not evaluated in this report. The functions of the heaters are not evaluated in this report except as part of the pressure boundary for the BWST. The BWST heaters have ACTIVE functions that will proceed to the Condition Monitoring path. The BWST at Davis Besse is not equipped with heaters. Davis Besse uses a heat exchanger to heat the BWST. The heat exchanger for the BWST at Davis Besse is not evaluated in this report since it is external to the BWST and is not a generic component.

Section 1.2 and 1.3 of this report describes the ITLR Systems/Components and their ITLR functions. Section 1.4 and 1.5 provide a detailed component description and description of operation for the BWST.

1.2 System ITLR Functions

Listed below are each plants DHRS ITLR Functions.

ARKANSAS ONE-1

1. Transfer heat from the reactor core following a LOCA.
2. Provide borated water from the BWST under accident conditions at sufficient concentration to assure shutdown margin and in sufficient supply to fill the RB to an adequate level for recirculation from the RB sump.
3. Provide water to the Building Spray pump suction piping from the BWST and RB sump.
4. Supply water to the HPI pump suction piping from the BWST and RB sump for long term core cooling following a small break LOCA.
5. Provide long-term heat removal from the RB following a LOCA to reduce RB temperature and pressure.
6. Support spent fuel storage control by providing a pathway for SF pool makeup.
7. Provide long-term RCS heat removal by recirculation of the RCS and heat rejection to the SW system.
8. Provide RCS recirculation for boron mixing.
9. Maintain reactor coolant pressure boundary integrity and containment isolation of penetrations that do not serve any accident-consequence-limiting system function.
10. Provide electrical isolation of non-safety-related portions of DHR/LPI from safety-related power supplies.
11. Provide indication of DHR return line isolation.
12. Provide RB water level indication.

CRYSTAL RIVER-3

1. LPI provides borated water to the core for short term cooling and reactivity control.
2. Long term cooling and reactivity control by recirculation of borated water from RB sump.
3. Provide suction head for HPI pump in "piggyback" mode for SBLOCA.
4. Prevent boron stratification/precipitation in the core following LOCA.
5. Support RB heat removal by cooling RB sump fluid during post LOCA recirculation.

Davis Besse-1

Not available.

OCONEE

1. Provide injection of borated fluid from the BWST after postulated Design Basis Events (DBEs) to assure adequate shutdown margin and core cooling.
2. Provide for long term heat removal after Loss of Coolant Accidents (LOCAs) by recirculating fluid from the emergency reactor building sump.
3. Provide a flow path form the BWST to the HPI and Reactor Building (RB) spray pumps.
4. Supply water from the RB emergency sump to the HPI and RB spray pumps after a small break LOCA (piggy-back mode).
5. Provide long term Reactor Coolant System (RCS) heat removal by recirculation of the RCS fluid and heat rejection to the LPSW.
6. Provide RCS circulation for boron mixing (includes dump-to-sump function) to prevent boron precipitation.
7. Provide RCS pressure control while operating in decay heat removal mode.
8. Provide RCS pressure boundary integrity.
9. Provide containment isolation of penetrations.
10. Provide source of RCS inventory addition (Fire Protection, Station-Black-Out).

THREE MILE ISLAND-1

1. Provide makeup for LOCA via LPI & HPI for SBLOCA after BWST drained.
2. Provide water source for RB Spray.
3. Provide RB sump sampling and pH control.
4. Provide RB isolation.
5. Provide makeup/emergency boration via HPI following SBLOCA.
6. Provide long term core cooling following SBLOCA (piggyback).
7. Provide containment isolation.
8. Provide chemistry control to RCS.

1.3 Component ITLR Functions

The BWST must support the following ITLR component functions to support the operation of the DHRS at each plant.

1. Maintain pressure boundary.
2. Maintain inventory of borated water in tank.

1.4 Component Description

The BWST is a vertical, cylindrical tank located outside the Reactor Building and the Auxiliary Building. The BWST contains a sufficient amount of borated water for refueling operations and ECCS requirements. The BWST contains pure water with boron in solution. It is used as a source for emergency core-cooling injection, filling the fuel-transfer canal during refueling, the Reactor Building Spray System, the DHRS, and the Makeup and Purification System.

The BWST has the capacity to supply borated water for ECC and reactor building spray in the event of a LOCA. The original nominal BWST capacity is based on refueling volume requirements, which vary from plant to plant. Each plant has Technical Specification LCOs which require a minimum level of borated water and boron concentration in the tank. The boron concentration is set at the amount of boron required to maintain the core one percent Δk/k subcritical at 70°F without any control rods in the core. The boric acid concentration is between 10,300 ppm and 13,000 ppm for most plants. The pH at 77°F is -4.6 for 10,800 ppm and -4.5 for 13,000 ppm boric acid.

A level transmitter monitors BWST level and provides an input to a level indicator in the Control Room. The gauge indicates BWST level over a range from 0 to maximum number of gallons. The level transmitter also provides an input to the level switch which will annunciate the "BWST Level HI-LO" alarm if the level increases above the maximum or decreases below the minimum water level.

The BWST was designed to AWWA-D100. The BWST is designed to operate at atmospheric pressure and has a design temperature of 150°F. The BWST is not required to take the unit to cold shutdown, however the BWST is an alternate supply of borated water for reaching cold shutdown. The BWST is Seismic Category I, but is not designed to withstand the forces of a tornado. The design pressure requirements for the BWST state that the tank must be able to withstand an internal pressure equal to a column of water 10 feet above the top of the liquid which the tank may contain.

The BWST is equipped with Chromalox immersion heaters at all B&W plants except Davis-Besse. The heaters control the borated water temperature to prevent crystallization and local freezing of the boric acid. The heaters are controlled by a thermostatic switch set to maintain BWST water temperature from 65 to 85°F. Table 1.1 shows the minimum BWST water temperature at each of the plants. The heaters can be turned on and off locally by a handswitch. The heaters will automatically cut off if BWST temperature reaches a set temperature or if water level decreases to a set level from the bottom of the tank. The tank is insulated such that, if all heaters were lost, temperature within the tank would decrease at only 5°F per week, assuming the outside temperature is 19°F.

The BWST at Davis-Besse is equipped with a Recirculation Heat Exchanger instead of heaters. The recirculation flowpath contains a pump and a heat exchanger. The heat exchanger is heated by steam from the auxiliary steam system. The system is used to maintain the BWST water temperature between 50 and 90°F. The temperature is required to be greater than 35°F, which is the design basis for the containment vessel vacuum breaker sizing.

1.5 Component Operation

The BWST provides water for the following functions:

1. To the Spent Fuel Pool Cooling System for filling.
2. To the High Pressure Injection (HPI) System for Emergency Core Cooling (ECC) and for testing the HPI pumps.
3. To the Decay Heat Removal Pump for filling the Reactor Coolant System (RCS), filling the Refueling Canal, filling the Incore Tank, ECC and for testing the Decay Heat Removal pumps.
4. To the Containment Spray System for emergency operation and for testing of the Containment Spray Pumps.
5. To the Makeup and Purification System for transfer to the RCS.

The BWST is used in the Spent Fuel Pool Cooling System to drain the fuel transfer canal (FTC). The refueling canal is a passageway in the containment extending from the reactor vessel to the fuel transfer tube. This canal is filled with borated water during refueling. Once refueling is completed, the refueling canal water is drained and pumped to the BWST. After the refueling operation, the water in the BWST is recirculated through the spent fuel demineralizers to clean and reduce the activity of the water.

The operability of the BWST as part of the ECCS ensures that a sufficient supply of borated water is available for injection by the ECCS in the event of a LOCA. The HPI system uses high pressure injection pumps to pump borated water from the BWST into the RCS cold leg piping near the reactor inlet nozzles. The HPI pumps are capable of injecting BWST water into the RCS over the RCS pressure range of approximately 0 psig to 2400 psig RCS pressure. A normally open minimum flow recirculation line from each HPI pump to the BWST prevents the pumps from operating in a zero or low flow condition should RCS pressure exceed the pump shutoff head.

The Low Pressure Injection (LPI) System also injects water from the BWST and is capable of injecting BWST water into the RCS over the RCS pressure range of approximately 0 psig to 185 psig, with an injection rate of 3000 gpm at 100 psig RCS pressure. The Containment Spray System pumps also draw water from the BWST and inject it into the containment building through spray nozzles for reducing containment building pressure after a LOCA.

The BWST provides suction for the Containment Spray pumps during the initial injection mode. The BWST is also used as a water source during Containment Spray pump testing.

The Make Up pumps can take suction from the BWST through three-way valves in the Make Up Tank outlet. This provides a large volume of borated water for makeup to the RCS in the event of a small break in the RCS and an alternate source of borated water (alternate to the boric acid addition tanks in the Chemical Addition System) for shutdown reactivity control.

FIGURE 1.1 - BORATED WATER STORAGE TANK

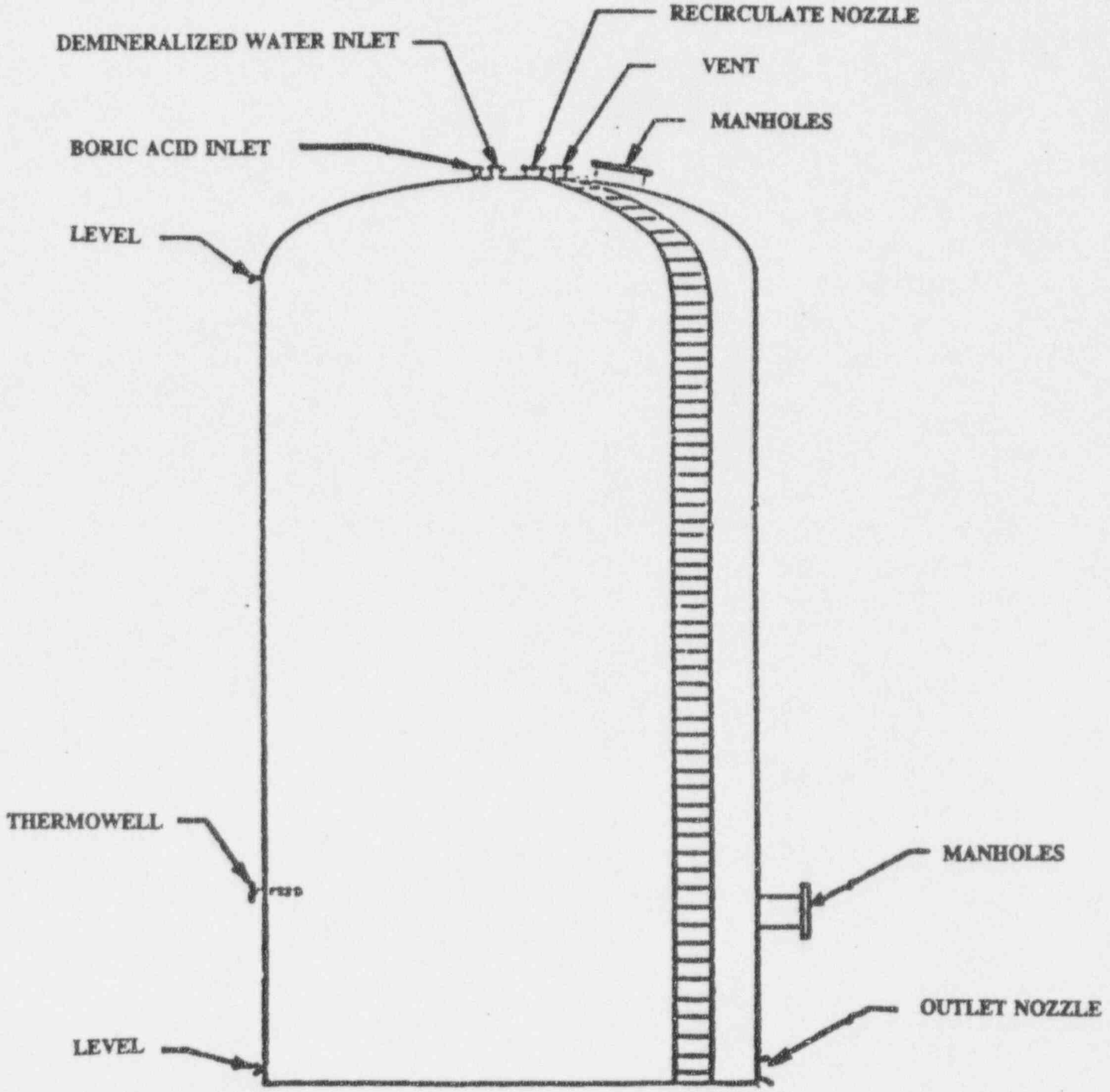

TABLE 1.1 - BWST DESIGN SPECIFICATIONS

Parameters	ANO-1 [6]	CR-3 [5]	DB-1 [4]	OC-1 [7]	OC-2 [7]	OC-3 [7]	TMI- [17]
Operating Capacity (gal)	350,000	449,000	550,000	390,000	390,000	390,000	352,000
Design Temperature (°F)	150	150	125	150	150	150	150
Minimum Temperature (°F)	40	40	35	50	50	50	40
Maximum Temperature (°F)	120	120	90	120	120	120	120
Operating Temperature (°F)	>65 <75	>65 <75	>65 <75	>65 <75	>65 <75	>65 <75	70
Boron Concentration (ppm)	2270 -2670	2270-2450	1800-2200	≥1950	≥1950	≥1950	≥2270
HEATERS	4	2	N/A	2	2	2	2
Manufacturer	Chromalox	Chromalox	N/A	Chromalox	Chromalox	Chromalox	Chromalox

2.0 Component Evaluation Basis

2.1 Component ITLR Function Classification

This section provides the basis for choosing the appropriate IPA Process flowpath for each BWST function. The B&WOG IPA process ensures that aging is adequately managed for ACTIVE and PASSIVE ITLR functions.

Block 3 in Figure 2.3 of the B&WOG GLRP Integrated Plant Assessment Process Demonstration (Summary Report) [16] takes credit for components that are routinely replaced and have a service life that is less than 40 years. Components that are credited for routine replacement are not subject to ARDUTLR. The BWST is not routinely replaced, so its evaluation proceeds to Block 4.

From Block 4 to the end of the IPA process, each component function is considered separately. The flowpath for ACTIVE functions (a function that requires mechanical motion or a change of state) will proceed to the Condition Monitoring path (Block 5). The flow path for PASSIVE functions (a function that is not an ACTIVE function) will be evaluated further to determine if a condition monitoring program is appropriate to manage aging in the renewal term. The classification of ITLR Functions as either PASSIVE or ACTIVE is based on the Generic Component Summary For GLR Program List [19]. The criteria used to determine whether a particular function can be assured with a condition monitoring program are found in Section 2.2 (Figure 2.3, Block 4) of the B&WOG GLRP Integrated Plant Assessment Process Demonstration. Further evaluation of ACTIVE ITLR functions, and PASSIVE ITLR functions which can be assured by a condition monitoring program, will continue in Sections 4.1 and 4.2 of this report. Evaluation of PASSIVE ITLR functions which cannot be assured by a condition monitoring program will continue in Section 2.3 of this report.

2.1.1 PASSIVE ITLR Functions

1. Maintain pressure boundary.

   Loss of this PASSIVE ITLR function would result in loss of pressure boundary for the DHRS.

2. Maintain inventory of borated water in tank.

   If the BWST does not maintain a proper inventory of borated water, the BWST will not be available for the plant to supply water for Emergency Core Cooling, filling the fuel-transfer canal during refueling, Reactor Building Spray System, Decay Heat Removal System, and the Makeup and Purification System.

Evaluation of these functions will continue in Section 2.3 of this report where BWST parts which support each ITLR function will be identified.

2.1.2 ACTIVE ITLR Functions

There are no ACTIVE Component ITLR Functions for the BWST.

2.2 Component Performance History

The historical review of the BWST utilized the following sources of information:

- o NPRDS
- o Past Availability Reports (annual)
- o Licensee Event Reports
- o B&WOG failure data from 1980-present (SM Stoller Corp.)
- o Task Force Reports
- o Working Group Reports

2.2.1 NPRDS Data

The Nuclear Plant Reliability Data System (NPRDS) indicates that there were 8 recorded problems with the BWST at Pressurized Water Reactors in the United States from July 1, 1974 to the present. Five of these reported problems were found from Routine Observations, one from Special Inspection\Test, one from Observations Abnormality and one from Incidental Observation.

Leakage of Borated Water

The largest cause of NPRDS recorded BWST problems were leaks at welds, fittings, nozzles or flanges of various pipes leading to or from the BWST. Four problems were detected by Routine Observation, one from Incidental Observation and one from Special Inspection/Testing.

Two of the reported problems noted above involved a weld in a seam of the BWST and were found during Routine Observation. The tanks were drained and the seams were re-welded. Four of the reported problems involved a leak of borated water at a flange or a nozzle connection. One incident found by Special Inspection/Test involved a pin-hole leak in the flange supplying BWST water to the containment spray pumps. After further analysis, it was noted that a through-wall axial crack occurred due to external stress corrosion cracking. This was a result of a break in the pipe and flange insulation which allowed moisture to collect and leach chlorides from the insulation onto the flange. The insulation was repaired and the flange section was removed and replaced. Another reported problem was detected by Routine Observation due to a leak from the 8 inch flange that connects the LPI recirculation line to the BWST. The probable cause of the leak was a degraded gasket. A new gasket was installed. The third flange problem was found by an Incidental Observation involving a leak of the flange connection to the containment spray suction pipe. After analysis, it was noted that the cause of this problem was attributed to a gradual deformation of the flange gasket due to wear. The gasket was replaced. The fourth reported problem was found by Routine Observation and involved external leakage around a 3 inch penetration nozzle on the BWST. It was reported that the problem was caused by galvanic coupling. Saturation of the insulation combined with rain water and chloride build up allowed severe pitting and localized corrosion of the nozzle.

There was no reported incident of BWST leakage causing an ITLR functional failure. Existing inspection programs have been effective in detecting and correcting leakage.

Heaters

Two reported incidents involved the heaters in the BWST. One problem was noted due to an Operational Abnormality detected when the BWST heater bank would not heat the BWST water. The problem was determined to be a loose connection at the power supply terminals which did not allow proper current flow to the heaters. The loose connections were tightened. The second reported incident was noted by Routine Observation when a BWST heater had leakage in the center tube area. The heater leakage was due to a defect in the center tube area where a thermowell is installed. The heater was replaced and a plug was installed into the center of the tube area to prevent premature leakage.

2.2.2 Past Availability and Plant Performance Committee Reports

B&WOG Failure Data (SM Stoller Reports) from 1980 to the present, indicated that there were no reported problems with the BWST at PWRs in the United States that resulted in a loss of availability.

2.2.3 License Event Reports (LER)

The License Event Reports (LER) prior to 1984 indicate that there were fifteen reported BWST incidents at PWRs in the United States. Thirteen of the fifteen LERs were reports of BWST borated water levels below Technical Specification LCOs. The low water level incidents were caused by unseated check valves, miscalibrated level indicators, addition of BWST water to another system when the BWST level was at a minimum level, and overfilling and overpressurization of the RCS during refueling. These reported problems do not deal with the integrity of the tank.

Two LERs were reports of leakage from the BWST. One incident involved a leak from a temporary level-indication line near the base of the BWST. The leak was repaired and the integrity of the piping and instrumentation in the area of the leakage was visually verified. The second report noted that after filling operations of the BWST, the contents of the tank were approximately 800 gallons below the minimum Technical Specification prior to the filling operation. An investigation indicated that there was an overall system leakage of approximately 0.75 gpm. The frequency of filling operations for the BWST was increased at that plant.

2.3 Component Parts Breakdown for PASSIVE ITLR Function Evaluation

2.3.1 Part Replacement Program

Block 8 in Figure 2.3 of the B&WOG GLRP IPA Process Demonstration is the ending point of the evaluation process for components that are routinely replaced (Block 3) and for component functions that will be adequately managed in the renewal term by existing programs (Block 5 and 10). Components that reach Block 8 are not subject to ARDUTLR for the function under evaluation. An adequate replacement program can cover both routine replacement or as-needed replacement based on component condition or performance. Component Parts which are included in a replacement program that meet the criteria in Section 2.2 of the B&WOG GLRP IPA Process Demonstration are not subject to ARDUTLR. All gaskets for the BWST are required to support the pressure boundary ITLR function for the BWST. However, this part is designed to be replaceable. Therefore, this part is not subject to aging unique to the license renewal period and does not require an ARDM evaluation.

2.3.2 Component Refurbishment

Block 9 takes credit for existing refurbishment programs to manage component aging. Refurbishment can have the same effect as component replacement: it reduces the effective time period over which aging can occur to something considerably less than the 40 year licensing period. The BWST as a whole is not subject to a routine refurbishment program as defined in Section 2.2 of the B&WOG GLRP IPA Process Demonstration.

2.3.3 Identification of Part/Material Combinations

Per Section 2.2 of the B&WOG GLRP IPA process demonstration the parts of the BWST which support the PASSIVE ITLR functions have been identified. They are:

- Shell
- Inlet Nozzle
- Outlet Nozzle
- Manway (side and roof)
- Recirculate Nozzle
- Overflow Nozzle
- Vents
- Drains
- Level Indicator Nozzle
- Temp. Well Nozzle
- Level Transmitter nozzle
- Heater Sheaths

- Bolts
- Studs
- Welds

Table 2.1 list the material of construction for these tank parts.

2.3.4 Protective Coatings

The shell of the BWST at ANO-1 and the shell and nozzles of the BWST at ONS-1,2 and 3 are fabricated from carbon steel material. The carbon steel material is primed with one coat of Plasite 7155 NP at 3 mils minimum dry film thickness. Then three coats of Plasite 7155 at 4 mils thickness each. Total dry film thickness of the coating system is 14.5 mils. Plasite is manufactured by Wisconsin Protective Coating Corporation and is a water resistant phenolic coating cross linked with epoxy resin and polymerized with an alkaline type curing agent. Laboratory tests were conducted on a mild steel test plate coated with Plasite 7155 at a thickness of 8 to 10 mils. The test plate was immersed in 25% boric acid, at temperatures of 70 to 80°F, for 6 months with no effect on the coating[15]. For this report, credit will be given for BWST parts coated with Plasite 7155. A one time inspection may be required at the plants which use a protective coating on BWST parts, to verify that the parts are still properly coated to prevent any potential ARDMs from occurring during the extended life of the plant.

TABLE 2.1 - MATERIAL SPECIFICATIONS FOR BWST

BWST Parts	Materials of Construction						
	ANO-1 [9,10]	CR-3	DB-1 [10,12]	ONS-1 [13]	ONS-2 [13]	ONS-3 [14]	TMI-1 [18]
Shell	ASTM A-131 CS (w/ Plasite 7155)	ASTM A-240 Type 304 SS	ASTM A-240 Type 304 SS	ASTM A-283 CS (w/Plasite 7155)	ASTM A-283 CS (w/Plasite 7155)	ASTM A-283 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Outlet Nozzle	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	ASTM A-240 Type 304 SS Rolled Plate	ASTM A-240 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Inlet Nozzle	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	N/A	ASTM A-240 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Recirculate Nozzle	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	N/A	ASTM A-312 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Vents	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	ASTM A-312 Type 304 SS	ASTM A-240 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Drain	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	ASTM A-312 Type 304 SS	ASTM A-240 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Level Indicator Nozzle	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	N/A	ASTM A-240 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	N/A
Temp. Well Nozzle	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	ASTM A-312 Tp.304 SS Pipe With ASTM A-182 F304 SS Flange	ASTM A-182 GR. F304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS

TABLE 2.1 - MATERIAL SPECIFICATIONS FOR BWST

BWST Parts	Materials of Construction						
	ANO-1 [9,10]	CR-3	DB-1 [10,12]	ONS-1 [13]	ONS-2 [13]	ONS-3 [14]	TMI-1 [18]
Manhole (Roof and Side)	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	ASTM A-240 Tp.304 SS Rolled Plate With ASTM A-182 F304 SS Flange	ASTM A-240 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Level Transmitter Nozzle	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	ASTM A-312 Tp.304 SS Pipe With ASTM A-182 F304 SS Flange	ASTM A-182 GR. F304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Overflow Nozzle	ASTM A-403 WP-304 SS ASTM A-182 F-304 SS	ASTM A-312 Tp.304 SS	ASTM A-240 Type 304 SS	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-181 CS (w/Plasite 7155)	ASTM A-240 Type 304 SS
Spent Fuel Cooling, Decay Heat Removal, and RB Spray Nozzles	N/A	ASTM A-312 Tp.304 SS	N/A	N/A	N/A	N/A	N/A
Chemical Addition Nozzle	N/A	ASTM A-182 F304 SS	N/A	N/A	N/A	N/A	N/A
Demineralized Water Nozzle	N/A	ASTM A-312 Tp.304 SS Pipe With ASTM A-182 F304 SS Flange	N/A	N/A	N/A	N/A	N/A
Heater Sheath	Incoloy	Tp.304 SS	N/A	Type 304 SS	Type 304 SS	Type 304 SS	ASTM A-316 SS
Heater Opening	N/A	ASTM A-240 Tp.304 SS Rolled Plate With ASTM A-182 F304 SS Flange	N/A	N/A	N/A	N/A	N/A
Studs	A-193 B-7 LAS	ASTM A-193 B8 SS	A-193 B-7 LAS	A-307 Gr. B CS	A-307 Gr. B CS	A-307 Gr. B CS	A-193 Gr. B8 SS
Bolts	A-194 Gr. 2H LAS	ASTM A-194 Gr.8 SS	A-194 Gr. 2H LAS	A-307 Gr. B CS	A-307 Gr. B CS	A-307 Gr. B CS	A-194 Gr.8 SS

TABLE 2.1 - MATERIAL SPECIFICATIONS FOR BWST

BWST Parts	Materials of Construction						
	ANO-1 [9,10]	CR-3	DB-1 [10,12]	ONS-1 [13]	ONS-2 [13]	ONS-3 [14]	TMI-1 [18]
Welds	see note (1)	see note (1)	see note (1)	see note (1)	see note (1)	see note (1)	see note (1)

ABBREVIATIONS: CS - CARBON STEEL SS - STAINLESS STEEL LAS - LOW ALLOY STEEL HAS - HIGH ALLOY STEEL

Notes: (1) Information concerning the material specification for the welds could not be located. However, it is assumed that the welds have corrosion-resistant properties equivalent to the base material.

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3.0 ARDM Assessment

This section refers to Block 10 of the IPA process. Block 10 contains the component and program evaluations for the ARDM path. The process focuses the program evaluation on those component parts that directly support the component ITLR function that is being evaluated. Parts that do not support the ITLR function will not be evaluated.

The ARDM's that were evaluated for the BWST are outlined in the GLRP ARDM Manual (to be completed in 1994). These ARDM's were selected so as to encompass known metallurgical degradation phenomena that can be evaluated on a component part basis. The review of industry data for the BWST (Sections 2.2.1 through 2.2.3 of this report) combined with the ARDM Manual form the basis for determining what additional age-management measures, if any, are needed for the BWST in the renewal term.

Table 2.1 shows that the parts that make up the BWST are fabricated from either stainless steel or carbon steel. The parts of the BWST which do not affect its ITLR functions were not evaluated in this report.

In Sections 3.1 through 3.14, the susceptibility of each BWST part to each ARDM is evaluated based on the material and operating conditions of the part. An ARDM is considered to be potential if one or more BWST parts are fabricated from a susceptible material, and are exposed to conditions which would promote the ARDM. Potential ARDMs will be carried forward to Section 3.14, where specific BWST Part/ARDM combinations will be identified. ARDMs that are not potential for the BWST will not be discussed in great detail in this report. Please refer to the GLRP ARDM Manual for further information.

3.1 Stress Corrosion Cracking (SCC)

SCC can be potential for stainless steel depending on applied stresses and the aggressiveness of the environment. Based on the low operating temperature and pressure of the BWST, applied tensile and residual stresses are expected to be minimal for stainless steel parts. Therefore, applied stresses are not a contributing factor to SCC for the BWST. Two other controlling contributing factors of SCC are dissolved oxygen concentration and the level of chloride in the water. Chemistry controls maintain the oxygen and chloride content of the BWST below levels conducive to SCC. Therefore the operating environment is not a contributing factor to SCC for the BWST. SCC is not a potential ARDM for stainless steel parts of the BWST.

Pressure vessel and piping steels have not demonstrated susceptibility to SCC in PWR environments, even with faulted water chemistry, and is not believed to be a failure concern [8]. Therefore, SCC is not a potential ARDM for carbon steel parts of the BWST.

3.2 Intergranular Attack (IGA)

Carbon and stainless steel parts can be susceptible to IGA, depending on the aggressiveness of the environment. Since the BWST has controlled water chemistry, it is not exposed to the environment necessary for IGA to occur. Therefore, IGA is not potential for BWST parts made of carbon and stainless steel.

3.3 Pitting & Crevice Corrosion

The water chemistry in the BWST is controlled to obviate pitting. However, the water in the BWST does contain a small amount of chloride ions. Carbon, low alloy and stainless steel are susceptible to pitting corrosion in the presence of chlorides. High temperatures, dissolved oxygen and stagnant fluid will aggravate pitting. Reactor coolant is maintained at water chemistry levels that would obviate the occurrence of pitting in the primary system. However, if chloride ions are present, then the potential for pitting increases in areas of minimal flow or stagnancy [8]. Even though the water in the BWST is mixed, areas of stagnancy could exist. Carbon steel parts of the BWST are coated with Plasite 7155 protective coating. Pitting is a potential ARDM for carbon steel parts coated with Plasite 7155 if the coating is cracked or chipped. Therefore pitting is a potential ARDM for stainless and carbon steel parts of the BWST.

Pitting has occurred in Inconel in steam generator tubing in some PWR plants. Pitting of Inconel occurs at a temperature range between 212 and 392°F [8]. The temperature range of the BWST is between 40 and 90°F, therefore Pitting is not a potential ARDM for Inconel parts of the BWST.

Crevice corrosion is not a potential ARDM for the BWST. The occurrence of crevice corrosion is dependent on the presence of dissolved oxygen in water above 500°F. In systems with extremely low oxygen content (< 0.1 ppm), crevice corrosion is considered to be insignificant [8]. The water chemistry in the BWST is controlled and the content of dissolved oxygen is less than 0.1 ppm. Also, the operating conditions of the BWST is between 35 to 90°F and the design temperature of the tank is 150°F. Therefore, crevice corrosion is not a potential ARDM for the BWST.

3.4 Uniform Attack/General Corrosion

General corrosion is not a potential ARDM for the BWST tanks made from stainless steel. General corrosion is generally not a concern in PWRs [8]. General corrosion is a potential ARDM for carbon steel parts and carbon steel clad with stainless steel parts. If the cladding or protective coating is flawed such that the underlying structural steel is in contact with the borated water, the structural steel may be subject to some general corrosion [8]. General corrosion is a potential ARDM for carbon steel parts with Plasite 7155 protective coating if the coating is chipped or flawed.

3.5 Erosion and Erosion-Corrosion

Erosion and Erosion-Corrosion is not a potential ARDM for stainless steel parts of the BWST.

Erosion and erosion-corrosion is a flow-assisted corrosion mechanism. Erosion and erosion corrosion is an inactive mechanism in the primary system. All materials in contact with the primary coolant are immune to erosion and erosion-corrosion [8]. Erosion and erosion-corrosion is not potential for carbon steel parts of the BWST due to low fluid flow and controlled water chemistry.

3.6 Microbiologically Influenced Corrosion (MIC)

MIC is an inactive mechanism in the primary, secondary, and service water systems treated for biological control [8]. MIC is not a potential ARDM for the parts of the BWST due to the BWST chemistry controls.

3.7 Neutron Irradiation Embrittlement

Neutron Irradiation Embrittlement is not a potential ARDM for the parts of the BWST.

3.8 Thermal Embrittlement

Since the BWST does not contain CASS parts, thermal embrittlement is not a potential ARDM for BWST parts.

3.9 Hydrogen Damage

Hydrogen damage is considered a non-potential ARDM for all parts of the BWST.

3.10 Fatigue

The temperature of the BWST can range from 35 to 90°F. During normal conditions and operation the BWST temperature ranges from 60 to 80°F. The alternating stresses due to temperature change is very small. Fatigue is not a potential ARDM for the BWST due to small alternating stresses.

3.11 Wear

Since the BWST is passive and there are no moving parts, wear is not considered a potential ARDM for the BWST.

3.12 Creep

Creep is not applicable to PWRs due to the high temperatures typical of creep [8]. Therefore creep is considered a non-potential ARDM for all BWST parts.

3.13 Stress Relaxation

The only parts of the BWST that are maintained in a condition of constant strain are bolts. Since the operating temperatures of the BWST are low, stress relaxation is not considered a potential ARDM for the BWST bolts.

Stress relaxation is considered a non-potential ARDM for all other non-bolting BWST parts.

3.14 Significant ARDM/ITLR Part Matrix

ARDM/Part combinations are identified in Table 3.1, the Potential ARDM Matrix for BWST Parts. Each ITLR part is evaluated for ARDM potential based on the material from which it was fabricated. All materials from which a part may have been fabricated are listed in the "Material" column. Shaded areas designate non-significant ARDM/Part combinations.

Some ARDMs were considered to be potential for carbon steel parts coated with Plasite 7155 since the protective coating could degrade and allow borated water to come in contact with carbon steel parts of the BWST. No information was available on the consequences of prolonged exposure of Plasite to boric acid and borated water.

TABLE 3.1 - POTENTIAL ARDM/BWST PARTS MATRIX

BWST PART	Material	ARDM	
		General Corrosion	Pitting
Shell	SA-283 CS (W/Plasite 7155) SA-131 CS (W/Plasite 7155)		
	SA-240,SA-182,SA-403 SS		
Outlet Nozzle	SA-283 CS (W/Plasite 7155) SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403 SS		
Inlet Nozzle	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403 SS		
Recirculate Nozzle	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403, SA-312 SS		
Vents	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403, SA-312 SS		
Drain	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403, SA-312 SS		
Level Indicator Nozzle	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403 SS		
Temp. Well Nozzle	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403, SA-312 SS		
Manholes	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403 SS		
Level Transmitter Nozzle	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403, SA-312 SS		
Overflow Nozzle	SA-181 CS (W/Plasite 7155)		
	SA-240, SA-182, SA-403, SA-312 SS		

TABLE 3.1 - POTENTIAL ARDM/BWST PARTS MATRIX

BWST PART	Material	ARDM	
		General Corrosion	Pitting
Spent Fuel Cooling, Decay Heat Removal, and RB Spray Nozzles	SA-312 Tp.304		
Chemical Addition Nozzle	SA-182 SS		
Demineralized Water Nozzle	SA-312, SA-182 SS		
Heater Opening	SA-240, SA-182 SS		
Heater Sheath	SA-304,SA-316 SS, Incoloy		
Studs	SA-193, SA-307 CS		
	SA-193 B8 SS		
Bolts	, SA-307 CS		
	SA-194 Gr.8, SA-194 Gr.2H SS		
Welds	CS (W/Plasite) - see note (1)		
	SS - see note (1)		

notes: (1) Information concerning material specifications for the welds could not be located. However, it is assumed that the welds have corrosion-resistant properties equivalent to the base material.

(2) Shaded areas represent non-significant ARDM/Part combinations.

4.0 Existing Age Management Programs

Potential ARDMs are discussed in Section 3.0 and identified in Table 3.1. Existing programs that manage the potential ARDMs are discussed in this Section. The programs discussed in Section 4.1 are programs currently required by ASME Section XI. Some plants that have not yet adopted ASME Section XI editions after 1986 and are not currently conducting the ISI programs noted below. However, since all plants update their ISI 10-year programs, the noted requirements will be required to be conducted for future ISI 10-year inspection plans. In Section 4.2 programs currently in effect at the plants due to Technical Specification LCOs and other implemented programs are also discussed.

4.1 1989 ASME Section XI In-service Inspection Requirements, Subsection IWC

The 1989 ASME Section XI subsection IWC-1000 requires that a VT-2 visual inspection be conducted on only those portions of the system required to operate or support the safety system function up to and including the first normally closed valve or valve capable of automatic closure when the safety function is required. A system pressure test IWC-5221/or IWC-5222 is also required to be conducted with the VT-2 inspection for the BWST. Visual examination indications associated with the ISI inspection must be corrected if any of the relevant conditions of IWC-3516 are observed.

For pressure retaining welds in vessels, a volumetric examination is required and must be corrected if any of the relevant conditions of IWC-3510 are observed.

Visual Examination VT-2

A Visual Examination VT-2 shall be conducted to locate evidence of leakage from pressure retaining components, or abnormal leakage from components with or without leakage collection systems as required during the conduct of system pressure or functional test.

A VT-2 visual examination is conducted on the outside of the BWST shell and would detect deterioration on the outside of the tank around bolted closures. However, inside surface of the tank would not be examined. Deterioration of the protective coating or material of fabrication of the tank would not be detected by an exterior VT-2 visual examination. A one-time inspection is discussed in Section 5.1 of this report to manage potential ARDMs of the interior surface of the BWST.

IWC-5221 System Pressure Test During System Functional and System In-service Tests

(a) The nominal operating pressure of the system functional test shall be acceptable as the system test pressure. (b) The nominal operating pressure during system operation shall be acceptable as the test pressure for the system in-service test.

IWC-5222 System Hydrostatic Test

(b) In the case of atmospheric storage tanks, the nominal hydrostatic pressure, developed with the tank filled to its design capacity, shall be acceptable as the system test pressure. For 0-15 psi storage tanks, the test pressure shall be 1.1 P_G Design Pressure of vapor or gas space above liquid level for which overpressure protection is provided by relief valves.

A System Hydrostatic/System Pressure Test would indicate leakage of the BWST. Either of these tests would indicate potential problems with the tank and would require further investigation by the plant prior to the plant going on line.

Volumetric Examination

A volumetric examination indicates the presence of discontinuities throughout the volume of material and may be conducted from either the inside or outside surface of a component. It may be conducted by either of the following methods: radiographic, ultrasonic, or eddy current.

The volumetric examination is required for all pressure retaining welds in the BWST. The results of the volumetric examination are recorded and if the results of the examination must be corrected if they exceed the relevant conditions of IWC-3510. The volumetric examination will detect problems with welds in the BWST and potential problems with welds will be monitored and recorded during this inspection.

4.2 Other Inspection Programs

Technical Specification LCO Requirements

To meet the Technical Specification LCO requirements for each plant the following measurements and readings must be taken:

BWST Level

All plants check that the BWST level is maintained at the required level as stated in the Technical Specification LCOs for each plant.

BWST Temperature

All plants check the BWST water temperature daily according to Technical Specification LCOs for each plant.

BWST Water Chemistry Control

All plants check the BWST water chemistry control according to Technical Specification LCOs for each plant.

Note that some ARDMs were considered non-potential for this report based on programs/tests conducted for the Technical Specification LCO requirements. The LCO programs/tests are discussed in this section for general information on existing programs in place at B&W nuclear plants for the BWST.

LCO requirements, instrumentation, and current (ASME Code 1989 Edition) ISI programs provide reasonable assurance that the BWST will continue to perform its ITLR functions over the extended operating period associated with license renewal given that:

(a) The tank protective lining remains intact.
(b) Pitting of stainless steel parts and bolting corrosion do not compromise integrity of the tank.

Section 5.0 contains recommendations to deal with these possibilities.

5.0 Recommendations for Age-Management Programs

5.1 One Time Inspections

For BWST parts coated with Plasite 7155 protective coating, it is recommended that a one time inspection be conducted to verify that the protective coating is still intact throughout the BWST. A film thickness of 14.5 mils was recommended by the manufacturer for initial application. It is recommended that an inspection be conducted prior to the license renewal period to verify that all carbon steel parts coated with Plasite 7155 are still completely coated and that no signs of aging or potential ARDMs exists for these parts.

For stainless steel BWST parts, it is recommended that a one time inspection be conducted to verify that there are no signs of pitting.

A one-time inspection is recommended for the interior of the BWST to verify that aging degradation has not occurred in the interior of the tank prior to the license renewal period. Current inspection programs do not monitor the interior surfaces of the tank and design specifications for the tank did not specify a service life for the BWST. A one-time inspection will provide reasonable assurance that the current BWST programs will adequately manage aging over the extended life of the tank.

5.2 General Recommendations

From the technical information gathered for the ARDM section of this report, it was noted that BWST insulation that was damaged allowed moisture to collect and leach chlorides from the insulation onto the parts of the BWST (Section 2.2.1). The leaching of chlorides caused a potential for SCC to occur at the locations where the insulation was damaged. Plants that may have had this problem should replace the damaged insulation and inspect for indications of SCC. In the event that insulation damage should occur in the future, it is recommended that the utility replace the damaged insulation and inspect for indications of SCC.

6.0 References

1. Davis Besse System Description "Decay Heat Removal System SD42"

2. Davis Besse System Description "High Pressure Injection System"

3. Davis Besse Updated Safety Analysis Report Volume 10, Section 9.3.5

4. Davis Besse Technical Specifications Section 2.4

5. Crystal River Technical Specifications Section 3.5.4, 4.5.4

6. Arkansas Nuclear One Unit One Technical Specifications Section 3.3

7. Oconee 1,2 and 3 Technical Specifications Section 3.3.

8. BWNT Document, "B&WOG GLRP ARDM Manual", Working Draft (to be released in 1994).

9. Specification for Borated Water Storage Tank for ANO-1, Specification No. 6600-M-291 Job No. 6600.

10. Specification for Desiging, Furnishing, Fabrication, Delivery and Erection or Field Erected Storage Tanks DB-1, Specification No. 7749-C-34 Job No. 7749.

11. Bechtel Corporation Drawing No. C-46, Arkansas Power & Light Company Arkansas Nuclear One, "Field Erected Tanks Sheet No.2".

12. Chicago Bridge & Iron Company Drawings 6,7,9,10,and 14, Contract No. 71-2051, Davis Besse Nuclear Power Plant.

13. Oconee-1 Drawing Numbers 36-44-001,36-44-012,36-44-005.

14. Oconee-3 Drawing Numbers 36-44-001,36-44-006,36-44-00736-44-013.

15. VSMF Tapes, Plasite Corrosion Resistant Coatings - Technical Bullentin August 1984.

16. BWNT Document No. 47-1228802-00, "B&W Owners Group Generic License Renewal Program Integrated Plant Assessment Process Demonstration (Summary Report)".

17. GPU Nuclear Operating Procedure Number 1101-1 "Plant Limits and Precautions " Revision 27.

18. Pittsburgh-Des Moines Steel Co. Drawings 36-44-09,36-44-023, 36-44-021, 36-44-003.

19. BWNT Document No. 51-1224979-04, "Generic Component Summary For GLR Program".