QUAD CITIES 1 & 2

HYDROGEN WATER CHEMISTRY INSTALLATION COMPLIANCE
WITH THE
ELECTRIC POWER RESEARCH INSTITUTE GUIDELINES
FOR
PERMANENT BWR HYDROGEN WATER CHEMISTRY INSTALLATIONS

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Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
1.0 INTRODUCTION	**1.0 Comply with intent:** Design guidance provided in this section does not include any requirements.

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2.0 GENERAL SYSTEM DESCRIPTION	**2.0 Comply with intent:**
Figure 2-1 shows the hydrogen addition system in simplified form. For this report, the system is divided into hydrogen supply, oxygen supply, hydrogen injection, and oxygen injection systems. Options for hydrogen supply are discussed briefly below, and detailed descriptions of the main options are provided in Section 3. Oxygen supply is also described in Section 3. The gas injection systems are described in this chapter. Also described in this chapter are instruments and controls applicable to the entire system.	Design guidance provided in this section does not include any requirements.
2.1 GENERAL DESIGN CRITERIA	**2.1 Comply with intent:**
The hydrogen water chemistry system is not safety-related. Equipment and components need not be redundant (except where required to meet good engineering practice), seismic category I, electrical class IE, or environmentally qualified. Nevertheless, proximity to safety-related equipment or other plant systems requires special consideration in the design, fabrication, installation, operation and maintenance of hydrogen addition system components. Section 9 of this document delineates the quality assurance and quality control requirements to assure a safe and reliable hydrogen addition system. In some cases these requirements are over and above those which are normally required for nonsafety-related installations. The hydrogen addition system should suppress the dissolved oxygen concentration in the recirculation water to a point where IGSCC immunity is maintained at all reactor power levels at which the hydrogen addition system is operating.	See Section 2.0.

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2.2 HYDROGEN SUPPLY OPTIONS Hydrogen can be supplied from three sources: (1) a commercial hydrogen supplier; (2) onsite production from raw materials; or (3) recovery and recycle of hydrogen from the off-gas system. Any combination of these three methods may, in principle, be appropriate at a given facility.	**2.2 Comply with intent:** See Section 2.0.
2.2.1 Commercial Suppliers Hydrogen can be obtained commercially from two types of sources: (1) merchant producers (i.e., companies that make hydrogen for the purpose of selling it to others) and (2) byproduct producers (i.e., companies that produce hydrogen only as a byproduct of their main business). Hydrogen obtained in this manner is supplied as a high pressure gas or as a cryogenic liquid. The selection of gaseous or liquid supply options depends on system requirements such as flow rates and injection pressures and onsite considerations such as available separation distances and building strengths. In general, gaseous storage is preferred for low flow rates and small separation distances. Detailed considerations for gaseous and liquid hydrogen supply facilities are described in Sections 3.1 and 3.2 of this report, respectively. Safety considerations are discussed in Sections 4.1 and 4.2.	**2.2.1 Comply:** Hydrogen will be initially supplied by a merchant producer.
2.2.2 Onsite Production Industrial processes for hydrogen production can be divided into two groups: electrolysis of water and thermochemical decomposition of a feedstock that contains hydrogen. Detailed considerations for onsite production of hydrogen by electrolysis are described in Section 3.3 of this report.	**2.2.2 Not Applicable:** Onsite production will not be used for the initial design.

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All other processes for producing high purity hydrogen involve thermochemical decomposition of hydrogen-containing feedstocks followed by a series of chemical and/or physical operations that concentrate and purify the hydrogen. While these processes are feasible, in principle, they are not currently envisioned for implementation. Therefore, these processes are not addressed in this report.	
2.2.3 Recovery Many processes are commercially available for separating, concentrating, and purifying hydrogen from refinery or by-product streams or for upgrading the purity of manufactured hydrogen. Processes are also being developed for the recovery and storage of hydrogen by the formation of rechargeable metal hydrides. Although recovery of hydrogen is a viable option, near-term implementation of this option is not envisioned. Therefore, this option is not addressed in this report.	**2.2.3 Not Applicable:** A recovery method will not be used for the initial design.
2.3 GAS INJECTION SYSTEMS	
2.3.1 Hydrogen Injection System The hydrogen injection system includes all flow control and flow measuring equipment and all necessary instrumentation and controls to ensure safe, reliable operation.	**2.3.1 Comply:**
2.3.1.1 Injection Point Considerations Hydrogen shall be injected at a location that provides adequate dissolving and mixing and avoids gas pockets at high points. Experience has shown that injection into the suction of feedwater or condensate booster pumps is feasible. Injection into feedwater pumps will require hydrogen at high pressures (e.g., 150-600 psig). This may require either a compressed gas supply, compressors or a cryogenic hydrogen pump, depending on	2.3.1.1 Comply: Hydrogen is injected at the condensate pump discharge through gas saver lance assemblies

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the supply option chosen. In the case of a liquid hydrogen storage system, this can also affect the sizing of the liquid hydrogen tank.	
There may be pressure fluctuations in feedwater systems, depending on reactor power level and pump performance. The hydrogen addition system shall be designed to accommodate the full range of such fluctuations.	
2.3.1.2 Codes and Standards	2.3.1.2 (Paragraphs 1 through 5) Comply with intent: Codes and standards used for the hydrogen injection system are equivalent to or more strigent than those identified in this section.
This system shall be designed and installed in accordance with OSHA standards in 29 CFR 1910.103.	
Piping and related equipment shall be designed and fabricated to the appropriate edition of ANSI B31.1 or B31.3 for pressure-retaining components. Storage containers, if used, shall be designed, constructed, and tested in accordance with appropriate requirements of ASME B&PV Section VIII or API Standard 620. All components shall meet all the mandatory requirements and material specifications with regard to manufacture, examination, repair, testing, identification and certification.	
All welding shall be performed using procedures meeting requirements in AWS D1.1, ANSI B31.1 or B31.3, or ASME B&PV, Section IX, as appropriate.	
Inspection and testing shall be in accordance with requirements in ANSI B31.1, ANSI B31.3, or API 620, as appropriate.	
System design shall also conform with pertinent portions of NUREG-0800, 10 CFR 50.48, Branch Technical position BTP CMEB 9.5-1, and appropriate standards and regulations referenced in this document. Appendix A provides a list of codes, standards, regulations, and published good engineering practices applicable to permanent hydrogen water	

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chemistry installations. Each utility is responsible for identifying additional plant-specific codes and standards that may apply, such as State-imposed requirements, Uniform Building Code, ACI or AISC standards.	
Piping and equipment shall be marked or identified in accordance with ANSI Z35.1.	2.3.1.2 (Paragraph 6) Do not comply: See Section 10.1 of the Hydrogen Water Chemistry license package for justification for noncompliance.
2.3.1.3 <u>System Design Considerations.</u> Hydrogen piping from the supply system to the plant may be above or below ground. Piping below ground shall be designed for cathodic protection (or be coated and wrapped), the appropriate soil conditions such as frost depth or liquefaction, and expected vehicle loads. Guard piping around hydrogen lines is not required; however, consideration shall be given to its use for such purposes as protection from heavy traffic loads, leak detection and monitoring, or isolation of the potential hazard from nearby equipment, etc. All hydrogen piping should be grounded and have electrical continuity.	2.3.1.3 Comply:
Excess flow valves should be installed in the hydrogen line at appropriate locations to restrict flow out of a broken line. Excess flow protection shall be designed to ensure that a line break will not result in an unacceptable hazard to personnel or equipment (BTP CMEB 9.5-1). The design features for mitigating the consequences of a leak or line break must perform their intended design function with or without normal ventilation.	
Individual pump injection lines shall contain a check valve to prevent feedwater from entering the hydrogen line and to protect upstream hydrogen gas components. Automatic isolation valves should be provided in each injection line to prevent hydrogen injection into an inactive pump.	

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Purge connections shall be provided to allow the hydrogen piping to be completely purged of air before hydrogen is introduced into the line. Nitrogen or another inert gas shall be used as the purge gas. Gases shall be purged to safe locations, either directly or through intervening flow paths, such that personnel or explosive hazards are not encountered and undesirable quantities of gas are not injected into the reactor.	2.3.1.3 (Continued) Comply:
Area hydrogen concentration monitors are an acceptable way to ensure that hydrogen concentration is maintained below the flammable limit. If used, such monitors should be located at high points where hydrogen might collect and/or above use points that constitute potential leaks. Good engineering practice for locating hydrogen detector heads is to take into consideration the positive buoyancy of gaseous hydrogen. Detector heads shall be located so that the monitors shall be capable of detecting hydrogen leaks with or without normal ventilation. Each utility shall evaluate its particular system design and identify specific points where hydrogen concentration monitors should be installed. Examples of such points include flanged in-line devices (such as calibration spool pieces associated with mass flowmeters), outlets of purge/vent paths, or the items discussed in the following paragraph. Sleeves or guard pipes can be used as an alternative method to mitigate the consequences of a line break.	
A hydrogen addition system will increase the hydrogen concentration in the feedwater, reactor, steamlines and main condenser. Each of these systems shall be reviewed for possible detrimental effects. A discussion of possible concerns is presented below.	
• **Main Condenser.** The main condenser presently handles combustible gases. The hydrogen addition system does not significantly change the	

concentration or volume of noncondensables. Therefore, it is not anticipated that hydrogen addition will affect operation of the main condenser.

- **Off-Gas System.** Oxygen shall be added into the off-gas system to recombine with the hydrogen flow thus limiting the extent of the system handling hydrogen rich mixtures and reducing volumetric flow rates. The net effect will probably be a revised heat input into the recombined off-gas. The capability of the off-gas system to handle this revised heat load must be evaluated to ensure that temperature limits are not exceeded. Considerations in the design of the off-gas oxygen injection system should include loss of oxygen and runaway oxygen injection.

- **Steam Piping and Torus.** Hydrogen water chemistry may slightly increase the rate of hydrogen leakage into the torus via the safety relief valves. However, the rate of oxygen leakage will be decreased. Thus, the possibility of forming a combustible mixture is not significantly increased when compared to non-HWC operation.

- **Sumps.** There are three water systems that may be affected by HWC: main condenser condensate, feedwater and reactor water. For sumps, which receive water from any of these three sources, the average hydrogen concentration in the water may increase slightly. The maximum expected concentration of hydrogen in the sump atmosphere should be determined to ensure that the hydrogen concentration remains below the lower combustible limit of hydrogen in air.

2.3.1.3 (Continued) Comply:

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2.3.2 Oxygen Injection System The oxygen injection system injects oxygen into the off-gas system to ensure that all excess hydrogen in the off-gas stream is recombined. It includes all necessary flow control and flow measurement equipment.	**2.3.2 Comply:**
2.3.2.1 Injection Point Consideration Oxygen should be injected into a portion of the off-gas system that is already diluted such that the addition of oxygen does not create a combustible mixture. If this is not possible, other system design considerations shall be provided in plant-specific cases to reduce the chances for off-gas fires.	2.3.2.1 Comply: Oxygen is injected upstream of the first stage steam jet air ejector
2.3.2.2 Codes and Standards The system shall be designed and installed in accordance with OSHA standards in 29 CFR 1910.104, and CGA G4.4, Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems. Piping and related equipment shall be designed, fabricated, tested and installed in accordance with the appropriate edition of ANSI B31.1 or ANSI B31.3. Additional guidance on materials of construction for oxygen piping and valves is given in Section 3.4 of this report, and in ANSI/ASTM G63, "Evaluating Nonmetallic Materials for Oxygen Service." Welding shall be performed using procedures meeting requirements of AWS D1.1 or ASME B&PV, Section IX, as appropriate.	2.3.2.2 (Paragraphs 1, 2, 3, and 5) Comply with intent: Codes and standards used for the oxygen injection system are equivalent to or more stringent than those identified in this section.
Piping shall be marked or identified in compliance with ANSI Z35.1.	2.3.2.2 (Paragraph 4) Do not comply: See Section 10.1 of the HWC licensing package for justification for noncompliance.

System design shall also conform with appropriate NFPA, CGA, and other standards and regulations referenced elsewhere in this document. Each utility is responsible for identifying plant-specific codes and standards that may apply, such as State-imposed requirements, Uniform Building Code, ACI or AISC standards.

2.3.2.3 Cleaning

All portions of the system that may contact oxygen shall be cleaned as described in Section 3.4 of this report, and in accordance with CGA G-4.1, Cleaning Equipment for Oxygen Service.

2.4 INSTRUMENTATION AND CONTROL

This subsection discusses the instrumentation, controls, and monitoring associated with the hydrogen addition system.

The instrumentation and controls include all sensing elements, equipment and valve operating hand switches, equipment and valve status lights, process information instruments, and all automatic control equipment necessary to ensure safe and reliable operation. Table 2-1 lists the recommended trips of the hydrogen addition system. The instrumentation shall provide indication and/or recording of parameters necessary to monitor and control the system and its equipment. The instrumentation shall also indicate and/or alarm abnormal or undesirable conditions. Table 2-2 lists the recommended instrumentation and functions. This table also includes instrumentation for hydrogen and oxygen supply options. Additional information on instrumentation and controls is provided in Section 3.

System instrumentation and controls shall be centralized where feasible to facilitate ease of control and observation of the system. As a minimum, there shall be a system trouble alarm and/or annunciator provided in the main control room.

2.3.2.3 Comply with intent:

The oxygen piping was cleaned using procedures that met the requirements of CGA G-4.1 and G-4.4.

2.4 Do not comply:

See Section 10.2 of the HWC licensing package for justification of the following system trips which were not provided in the design of the HWC system.

a. High Residual Oxygen in Off-Gas Trip,
b. Low Oxygen Injection System Supply Pressure or Flow Trip, and
c. Off-Gas Train or Recombiner Train Trip

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2.4.1 Hydrogen Injection Flow Control Parallel flow control valves should be provided in the hydrogen injection line for system reliability and maintainability. If flow control is automatic, hydrogen flow rate should be controlled as a function of plant process parameters such as steam or feedwater flow. The capability should be provided to adjust flow rate to each pump manually, if this is found to be necessary to achieve adequate hydrogen distribution. Manual isolation valves shall be provided in each pump injection line to accommodate pump out-of-service conditions. Individual pump injection lines should contain automatic isolation valves interlocked to the corresponding pump, so that hydrogen is not injected into a pump that is not running. Provisions for shutoff of hydrogen injection shall be provided in the control room.	**2.4.1 Comply:**
2.4.2 Oxygen Injection Flow Control Parallel flow control valves should be provided in the oxygen injection line for system reliability and maintainability.	**2.4.2 (Paragraph 1) Comply with intent:** Only a single pure oxygen train is provided for each unit. The second train is from an air intake in the building. Each train has a single flow control valve.
Oxygen flow rate shall be controlled to provide residual oxygen downstream of the recombiners. System controls shall be designed to ensure that oxygen injection continues after hydrogen flow stops, so that all free hydrogen is safely recombined.	**2.4.2 (Paragraph 2) Comply:**
2.4.3 Monitoring Provision shall be made to monitor continuously the concentration of dissolved oxygen in the recirculation water. In obtaining samples of recirculation water for this purpose, appropriate containment isolation shall be provided in accordance	**2.4.3 Comply:**

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with 10 CFR 50, Appendix A, General Design Criteria 3, 54, 55, 56, or 57. Provision should be made to monitor continuously the concentration of oxygen and hydrogen in the off-gas flow downstream of the recombiners. Hydrogen and oxygen monitoring in the off-gas recombiner system should meet the acceptance criteria of Standard Review Plan 11.3 with the exception that automatic control functions are not required.	

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3.0 SUPPLY FACILITIES	
3.1 GASEOUS HYDROGEN	
3.1.1 System Overview	**3.1.1 Comply with intent:**
Hydrogen gas can be supplied from either permanent high-pressure vessels or from transportable tube trailers. For the permanent storage system, gaseous hydrogen is stored in seamless ASME code vessels at pressures up to 2,400 psig and ambient temperatures. Transportable vessels are designed to DOT standards and store hydrogen at pressures up to 2,650 psig at ambient temperatures. With either storage design, the gas is routed through a pressure control station which maintains a constant hydrogen supply pressure. In any event, the gaseous hydrogen system shall be provided by a supplier who has extensive experience in the design, operation and maintenance of associated storage and supply systems. Gaseous hydrogen shall be provided per CGA G-5 and G-5.3.	A hydrogen supplier has not been chosen at this time. When chosen, the hydrogen supplier will meet the intent of the criteria in this section.
3.1.2 Specific Equipment Description	
3.1.2.1 Hydrogen Storage Vessels	3.1.2.1 Not Applicable:
The hydrogen storage bank shall be composed of ASME Code gas storage vessels. Each tube shall be constructed as a seamless vessel with swagged ends. Specific tube design shall be based on ASME Unfired Pressure Vessel Code, Section VIII, Division 1, including Appendix XIV-70. The tube bank shall be supported to prevent movement in the event of line failure and each tube shall be equipped with a close-coupled shutoff valve. As an alternative, one safety valve per bank of tubes can be used, provided the safety valve is sized to handle the maximum relief from all tubes tied into the valve. Each bank shall be equipped with a thermometer and a pressure gauge, as is necessary for proper filling.	The interim hydrogen supply system will utilize transportable tube trailers and the long-term hydrogen supply system will utilize a cryogenic liquid hydrogen storage tank.

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3.1.2.2 Transportable Hydrogen Storage Vessel Transportable hydrogen vessels shall be constructed, tested, and retested (every 5 years), in accordance with DOT specifications 3A, 3AA, 3AX, or 3AAX. All valving and instrumentation shall be identical to Section 3.1.2.1.	3.1.2.2 Comply with intent: See Section 3.1.1
3.1.2.3 Pressure Reducing Station The pressure control station shall be of a manifold design. The manifold shall have two (2) full-flow parallel pressure reducing regulators. The discharge pressure range of these regulators shall be adjustable to satisfy plant hydrogen injection requirements. Pressure gauges shall be provided upstream and downstream of the regulators. Sufficient hand valves shall be provided to ensure complete operational flexibility. An excess flow check valve shall be installed in the manifold immediately downstream of the regulators to limit the flow rate in the event of a line break. The stop-flow setpoint shall be determined by each plant and should be set between the maximum plant flow requirements and the full C_v of the flow control valves. Additional guidance on excess flow protection is provided in Section 2.3.1.3.	3.1.2.3 Comply with intent: See Section 3.1.1
3.1.2.4 Tube Trailer Discharge Stanchion A tube trailer discharge stanchion shall be provided for gaseous product unloading. The stanchion shall consist of a flexible pigtail, shutoff valve, check valve, bleed valve, and necessary piping. Filling apparatus shall be separated from other equipment for safety and convenience, and protected with walls or barriers to prevent vehicular collision. A tube trailer ground assembly shall be provided for each discharge stanchion to ground the tube trailer before the discharge of hydrogen begins.	3.1.2.4 Comply with intent: See Section 3.1.1

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3.1.2.5 Interconnecting Pipeline	3.1.2.5 Comply with intent:
All equipment and interconnecting piping supplied with this system shall be installed in compliance with the following standards:	See Section 3.1.1
• American National Standards Institute (ANSI) B31.1, Power Piping, B31.3, Chemical Plant and Petroleum Refinery Piping.	
• National Fire Protection Association (NFPA) 70, National Electrical Code.	
• NFPA-50A, Bulk Hydrogen Systems.	
• All applicable local and national codes.	
There are several suitable field installation techniques which are based on industrial experience. The following are guidelines which may be used for field connections:	
• Copper-to-Copper, Brass-to-Brass, and Copper-to-Brass Socket Braze Joints. -- Silver Alloy 45% Ag, 15% Cu, 15% Zn, 24% Cd., ASTM B260-69T and AWS A5.8-69T, BAg-1 Melting Range-Solidus-607.2°C Liquidus-618.3°C -- Flux Working Range 593.3°C to 871.1°C	
• Copper, Brass, Carbon Steel, and Stainless Steel N.P.T. Threaded Joints.	

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-- TEFLON* Tape**	3.1.2.3 (Continued) Comply with intent:
SCOTCH*** Number 48 Tape** or equal. -195.5°C to +204.4°C 0 to 3,000 psig. Wrapped in direction of threads.	See Section 3.1.1
• Flange Joints (On all Materials).	
-- Ring Gasket Material Low Pressure (720 psig maximum)	
Precut T.F.E. impregnated asbestos, 1/6 inch thickness. Garlock 900 or equal. -1955°C to +168.3°C,) to 900 psig.	
-- Ring Gasket Material,, High Pressure	
FLEXITALLIC****Type. Material to be 0.175 inch thick 304 stainless steel with TEFLON filler and 0.125 inch carbon steel guide ring.	

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*TEFLON is a trademark of E. I. duPont de Nemours & Co., Wilmington, DE 19898.

**If tape is used, electrical continuity/grounding of each piping section should be confirmed.

***SCOTCH is a trademark of 3M Company, St. Paul, MN 55101.

****FLEXITALLIC is a trademark of Flexitallic Gasket Co., Bellmawr, NJ 08031.

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— Antiseize Compound For flange face, nut, and bolt lubrication. Halocarbon 25-5S grease or equal. -195.5°C to +176.6°C, 0 to 3,000 psig. DO NOT USE ON ALUMINUM, MAGNESIUM, OR THEIR ALLOYS UNDER CONDITIONS OF HIGH TORQUE OR SHEAR. • Carbon Steel, Stainless Steel, and Aluminum Alloys Socket and Butt Welds. — Welding Procedure Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), Shielded Metal Arc Welding (SMAW), or Plasma Arc Welding (PAW); with appropriate filler material and shielding gas. Proper surface and joint preparation (in regard to cleaning and clearances) should be exercised.	3.1.2.3 (Continued) Comply with intent: See Section 3.1.1
3.1.2.6 Component Cleaning All components that contact hydrogen must be free of moisture, loose rust, scale, slag, and weld spatter; they must be essentially free of organic matter, such as oil, grease, crayon, paint, etc. To meet these objectives, system components shall be cleaned in accordance with standard industrial practices, as recommended by the gas supplier, prior to and following system fabrication.	3.1.2.6 Comply with intent: See Section 3.1.1
3.2 LIQUID HYDROGEN	
3.2.1 System Overview Liquid hydrogen is stored in a vacuum-jacketed vessel at pressures up to 150 psig and temperatures up to -403°F (saturated). Based on data relating hydrogen injection pressures to BWR plant power levels, hydrogen supply from a liquid	**3.2.1 Comply with intent:** A liquid hydrogen supplier has not been chosen at this time. When chosen, the hydrogen supplier will meet the intent of the criteria in this section.

source can be provided directly from a tank or pumped into supplemental gaseous storage. Gaseous storage requirements are identified in Section 3.1 The required supply pressure shall be based on pressure requirements at the point of hydrogen injection and line losses from the hydrogen supply system to the injection point.

Feedwater pressure requirements and line losses must not exceed 120 psig if hydrogen is to be supplied directly from a liquid tank.

In any event, the liquid hydrogen system shall be provided by a supplier who has extensive experience in the design, operation and maintenance of associated storage and supply systems, such as cryogenic pumping. Liquid hydrogen shall be provided in accordance with CGA G-5 and G-5.3.

3.2.2 Specific Equipment Description

3.2.2.1 Cryogenic Tank.

Tanks for liquid hydrogen service are available with capacities between 1,500 gallons and 20,000 gallons. An "inner vessel" or "liquid container" is supported within an "outer vessel" or "vacuum jacket," with the space between filled with insulation and evacuated. Necessary piping connects from inside of the inner vessel to outside of the vacuum jacket. Gauges and valves to indicate the control of hydrogen in the vessel are mounted outside of the vacuum jacket. Legs or saddles to support the whole assembly are welded to the outside of the vacuum jacket.

Inner vessels are designed, fabricated, tested, and stamped in accordance with Section VIII, Division 1, of the ASME Code for Unfired Pressure Vessels. Materials suitable for liquid hydrogen service must have good ductility properties at temperatures of -422°F per CGA G-5. The

3.2.2.1 Comply with intent:

See Section 3.2.1

cryogenic operating temperatures of these vessels preclude material degrading mechanisms such as corrosion or hydrogen embrittlement. The constant operating vessel pressures assure that flaw growth due to cyclic stress loading will not occur. The inner vessel is subject to a required pressure test which ensures that no flaws exist that could cause a failure at or below the set pressure of the vessel's redundant relief devices. In addition to ASME Code inspection requirements, 100% radiography of the inner vessel longitudinal welds shall be completed. The tank outer vessel shall be constructed of carbon steel and shall not require ASME certification.

Insulation between inner and outer vessels shall be either perlite, aluminized mylar, or suitable equal. Fibrous or blanket insulation, such as bonded glass fibers or rock wool, shall not be used because of the potential for liquid-saturated missiles which would occur only as a result of vessel failure. The annular space should be evacuated to a high vacuum of 50 microns or less.

Tank control piping and valving should be installed in accordance with ANSI B31.1 or B31.3. All piping shall be either wrought copper or stainless steel. The following tank piping subsystems shall be provided:

- Fill circuit, constructed with top and bottom lines so that the vessel can be filled without affecting continuous hydrogen supply.
- Pressure-build circuit, to keep tank pressures at operational levels.
- Vacuum-jacketed liquid fill and pump circuits, where applicable.

3.2.2.2 Overpressure Protection System

Safety considerations for the tank shall be satisfied by dual full-flow safety valves and emergency backup rupture discs. The

3.2.2.2 Comply with intent:

See Section 3.2.1

primary relief system shall consist of two sets of a minimum of one (1) rupture disk and safety valve piped into separate "legs." Relief devices shall be connected in parallel with other relief devices. The system shall be coupled by a 3-way diverter valve or tie bar interlock so that one leg is opened when the other is closed. With this arrangement, a minimum of one safety valve and one rupture disk will be available at all times. The dual primary relief systems with 100% standby redundancy allows maintenance and testing to be performed without sacrificing the level of protection from overpressure.

The primary relief system shall comply with the provisions of the American Society of Mechanical Engineers (ASME) Pressure Vessel Codes and the Compressed Gas Association (CGA) Standards.

The tank shall also be supplied with a secondary relief system not required by the ASME Codes. This system shall be totally separate from the primary relief system. It shall consist of a locked open valve, a rupture disk, and a secondary vent stack. This rupture disk shall be designed to burst at 1.33 times maximum allowable working pressure (MAWP).

Supply system piping that may contain liquid and can be isolatable from the tank relief valves shall be protected with thermal relief valves. All outlet connections from the safety relief valves, rupture devices, bleed valves, and the fill line purge connections shall be piped to an overhead vent stack, per CGA G-5, Section 7.3.7.

Two relief devices shall be installed in the tank's outer vessel to relieve any excessive pressure buildup in the annular space.

Hydrogen tanks and delivery vehicles shall be grounded per CGA P-12, Sections 5.4.5 and 5.7.1.2. The storage system shall be protected from the effects of lightning per NFPA 78, Chapter 6.

3.2.2 (Continued) Comply with intent:

See Section 3.2.1

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Excess flow protection shall be added to the tank's liquid piping wherever a line break would release a sufficient amount of hydrogen to threaten safety-related structures. An acceptable methodology is identified in Section 4.2.2, "Pipe Breaks."	
3.2.2.3 Instrumentation The tank shall be supplied with a pressure gauge, a liquid level gauge, and a vacuum readout connection. These gauges are sufficient for normal monitoring of the tank condition. Instrumentation for remote monitoring, such as high/low-pressure switches, pressure and level transmitters, may be added. A listing of supply system instrumentation and control is identified in Section 2.4.	3.2.2.3 Comply with intent: See Section 3.2.1
3.2.2.4 Liquid Hydrogen Pump and Controls The liquid hydrogen pump shall be of proven design to provide continuous hydrogen supply in unattended, automatic operation. The following items comprise the more important system controls.	3.2.2.4 Comply with intent: See Section 3.2.1
3.2.2.4.1 Positive Isolation Valve A positive isolation valve shall be used to control the liquid feed into the pumping system per NFPA 50B. The valve shall be a failed-closed, pneumatically operated valve. The valve shall only be open during pump operation, shall close in any fault mode, and shall be able to be remotely overridden in case of emergency.	3.2.2.4.1 Comply with intent: See Section 3.2.1
3.2.2.4.2 System Overpressure Shutdown Although the system is protected by safety relief valves and rupture discs, system overpressure shall be avoided by shutting down the pumps at high pressure.	3.2.2.4.2 Comply with intent: See Section 3.2.1

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3.2.2.4.3 Temperature Indicating Switch	3.2.2.4.3 Comply with intent:
A temperature switch shall continuously monitor the downstream gas line for low temperature and shall trip the liquid pump to protect downstream equipment from low temperatures.	See Section 3.2.1
3.2.2.4.4 Pump operation	3.2.2.4.4 Comply with intent:
Pump operation shall be continuously and automatically monitored. Operation which results in pump cavitation, high temperature at the pump discharge, or low temperature downstream of the vaporizer shall cause the pump to be shut down by the remote control panel. The fault shall be indicated on the remote control panel by an audible alarm and light indication.	See Section 3.2.1
3.2.2.4.5 Purging of Controls	3.2.2.4.5 Comply with intent:
All electrical components in hydrogen service should be designed in accordance with NFPA 70. Only nitrogen or another inert gas shall be used for purging pump motors, control panels and valves.	See Section 3.2.1
3.2.2.5 Interface with Gaseous System	3.2.2.5 Comply with intent:
Liquid hydrogen pump systems typically require a gaseous storage system as a surge or backup to plant hydrogen supply. These storage systems shall be designed in accordance with Section 3.1, Gaseous Hydrogen. Whenever a gaseous backup is used in conjunction with a liquid hydrogen system, switchover controls shall be provided.	See Section 3.2.1
3.2.2.6 Vaporization	3.2.2.6 Comply with intent:
Vaporization of the liquid hydrogen shall be achieved by the use of ambient air vaporizers. Vaporizer design, installation and operation shall take guidance from NFPA 50A and 50B.	See Section 3.2.1

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
The vaporizer should feature a star fin design and aluminum alloy construction. For a combined liquid and gaseous storage system, the vaporizers used should have a design pressure consistent with plant injection pressure requirements. The units may be piped in parallel such that each unit can operate independently. Parallel vaporizer assemblies shall be sized for the peak hydrogen flow required for each plant and shall provide for periodic intervals for defrosting, as appropriate. Other atmospheric vaporization systems may be utilized if their capacity is demonstrated to be adequate for the plant flow and ambient conditions.	
For a pumped liquid only storage system, the vaporizer must withstand maximum pressures generated from the cryogenic pump. These vaporizers shall be equipped with stainless steel lining designed to 3500 psig.	
3.3. ELECTROLYTIC	
3.3.1 System Overview	**3.3.1 Not Applicable:**
The disassociation of water by electrolysis is an acceptable method of obtaining the gases needed for hydrogen water chemistry. This can be done on site and the gases can conveniently be generated at the rate used. The electrolytic gas generator should be proven equipment, the same as used in other industrial applications. Depending on the generator operating pressure, either hydrogen compressors or pressure breakdown (control) is utilized to match plant hydrogen injection pressure requirements. The electrolytic system shall be provided by a supplier who has extensive experience in the design, operation and maintenance of these systems.	The electrolytic method of producing hydrogen is not being considered at this time.

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
3.4 LIQUID OXYGEN	
3.4.1 System Overview	**3.4.1 Comply:**
Liquid oxygen is stored in a vacuum-jacketed vessel at pressures up to 250 psig and temperatures up to -251°F (saturated). Oxygen taken from the vessel shall be vaporized through ambient air vaporizers and routed through a pressure control station which maintains gas pressures within the desired range. The liquid oxygen system shall be provided by a supplier who has extensive experience in the design, operation and maintenance of associated storage and supply systems. Liquid oxygen shall be provided per CGA G-4 and G-4.3.	The HWC system contains an 11,000 gallon liquid oxygen tank.
3.4.2 Specific Equipment Description	
3.4.2.1 Cryogenic Tank. Tanks for liquid oxygen service, with capacities between 3,000 gallons and 11,000 gallons are similar in principle. An "inner vessel" or "liquid container" is supported within an "outer vessel" or "vacuum jacket," with insulation provided in the space between the tanks. Necessary piping connects from inside of the inner vessel to outside of the vacuum jacket. Gauges and valves to indicate the control of product in the vessel are mounted outside of the vacuum jacket. Legs or saddles to support the whole assembly are welded to the outside of the vacuum jacket.	3.4.2.1 Comply:
Inner vessels shall be designed, fabricated, tested and stamped in accordance with Section VIII, Division 1, of the ASME Code for Unfired Pressure Vessels. Materials suitable for liquid oxygen service must have good ductility properties at cryogenic temperatures of -300°F per CGA G-4. The outer vessel should be constructed of carbon steel and does not require ASME certification.	

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
Insulation between inner and outer vessels shall be either perlite, aluminized mylar or suitable equal. The annular space should be evacuated to a high vacuum of 50 microns or less.	
Tank control piping and valving should be installed in accordance with ANSI B31.1 of B31.3. All piping shall be either wrought copper or stainless steel. The following tank piping subsystems shall be provided:	
• Fill circuit constructed with top and bottom lines so that the vessel can be filled without affecting system operation. • Pressure-build circuit, to keep tank pressures at operational levels. • Economizer circuit, to preferentially feed oxygen gas from vessel vapor space to process.	
3.4.2.2 Overpressure Protection System. Safety considerations for the tank shall be satisfied by dual full-flow safety valves and emergency backup rupture discs. The primary relief system shall consist of two sets of one (1) safety valve and one (1) rupture disc piped into separate legs, coupled by a three-way valve. This dual primary relief system with 100% standby redundancy allows maintenance and testing to be performed without sacrificing the level of protection from overpressure.	3.4.2.2 Comply:
The primary relief system shall comply with the provisions of the ASME Pressure Vessel Codes and the Compressed Gas Association (CGA) Standards.	
Annular space safety heads shall be provided to relieve any excess positive pressure buildup which might result from a leak in an inner vessel. Supply system piping that may contain liquid can be isolatable from the tank relief valves shall be protected with thermal relief valves.	

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
The tank shall be supplied with a pressure gauge, a liquid level gauge, and a vacuum readout connection. These gauges are sufficient for normal monitoring of the tank condition. Instrumentation for remote monitoring, such as high/low-pressure switches, pressure and level transmitters may be added. A listing of supply system instrumentation and control is identified in Section 2.4.	
3.4.2.3 Vaporization. The vaporization of the liquid oxygen shall be achieved by the use of ambient air vaporizers.	3.4.2.3 (Paragraph 1) Comply:
The vaporizer should feature a star fin design and extruded aluminum alloy construction. The vaporizers shall have a minimum design pressure of at least 300 psig. The units shall be piped in parallel such that each unit can operate independently. Parallel vaporizer assemblies shall be sized to handle peak plant flow requirements and shall provide for periodic intervals for defrosting, as appropriate. Other atmospheric vaporization systems may be utilized if their capacity is demonstrated to be adequate for the plant flow and ambient conditions.	3.4.2.3 (Paragraph 2) Comply with intent: The vaporizers to be used feature a hex fin design.
3.4.2.4 Pressure Control Station. The pressure control station shall be of a manifold design. The manifold shall have two (2) full-flow parallel pressure reducing regulators. The discharge pressure range of these regulators shall be adjustable to satisfy plant oxygen injection requirements. Pressure gauges shall be provided upstream and downstream of the regulators and sufficient hand valves shall be provided to ensure complete operational flexibility.	3.4.2.4 Comply:
Protection of downstream equipment from low-oxygen temperatures shall be included in the system design.	

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation

3.4.3 Materials of Construction for Oxygen Piping and Valves

The design and installation of oxygen piping and related equipment shall be in accordance with ANSI B31.1 or B31.3 and the following guidelines for material selection for oxygen systems.

Observations of past oxygen fires indicate that ignition can occur in carbon steel and stainless steel piping systems operating at, or near, sonic velocity. Friction from high velocity particles is considered to be the source of ignition. Copper, brass, and nickel alloys have the characteristic of melting at temperatures below their respective ignition temperatures. This makes these materials extremely resistant to ignition sources, and once ignited, they exhibit a much slower rate of burning than carbon or stainless steels.

As a result of these observations, the following materials, in order of preference, are acceptable for oxygen service. In the case of carbon steel or stainless steel, the maximum velocity of gaseous oxygen shall be within guidelines established by the Compressed Gas Association CGA Pamphlet CGA-4.4, "Industrial Practices for Gaseous Oxygen, Transmission and Distribution Piping Systems."

- Copper
- Brass
- Monel
- Stainless Steel
- Carbon Steel

If steel pipe is to be used for the system and some local flow conditions could cause the velocity to exceed that established in CGA G-4.4, then that portion of the system must be converted to a copper-based alloy and extend a minimum of 10 diameters downstream of the point of return to

Implementation or Justification for Nonconformance

3.4.3 Comply:

the allowable velocity. These local flow conditions may occur at control valves, orifices, branch line takeoff points, and in the discharge piping of safety relief devices.

Valves that open rapidly are not suitable for oxygen service, since rapid filling of an oxygen line will result in a temperature increase due to adiabatic compression. As a result of this phenomenon, ball valves and automatic valves may only be used with the following restrictions:

- Valve bodies shall be made of a copper alloy. Balls shall be monel or brass. Valve seats and seals should be teflon, nonplasticized Kel-F, Kalrez, or Viton.

  Ball valves may not be used as process control valves in throttling or regulating service. Ball valves may be used as isolation valves, emergency shutoff valves, or vent or bleed valves where they are either fully open or fully closed.

- Pneumatic or electric ball valves used for on-off services shall have an actuation time from fully closed to fully open of 4 seconds or greater for pressures up to 250 psig. No restriction is placed on actuation time from fully open to fully closed. Piping immediately downstream must be a straight run of copper-bearing material for a minimum of 10 diameters.

- Pneumatic or electric ball valves used for emergency service may be fully open or fully closed to the emergency position, with no restrictions on actuation time.

Suitable valve packing, seats, and gasket materials are listed below in order of preference from the oxygen compatibility basis only.

3.4.3 (Continued) Comply:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
• Teflon • Glass-filled Teflon • Nonplasticized Kel-F • Garlock 900 • Viton or Viton A	
3.4.4 Oxygen Cleaning	**3.4.4 Comply with intent:**
All piping, fittings, valves, and other material may contact oxygen shall be cleaned to remove internal organic, inorganic, and particulate matter in accordance with CGA 4.1. Observation has shown that ignition can occur in properly designed piping systems when foreign matter is introduced. Therefore, removal of contaminants such as grease, oils, thread lubricants, dirt, water, filings, scale, weld spatter, paints, or other foreign material is essential. Cleaning should be accomplished by precleaning all parts of the system, maintaining cleanliness during construction, and by completely cleaning the system after construction.	The oxygen supply system was cleaned using procedures that met the requirements of CGA G-4.1 and G-4.4.

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
4.0 SAFETY CONSIDERATIONS **4.1 GASEOUS HYDROGEN** **4.1.1 Site Characteristics of Gaseous and Liquid Hydrogen**	
4.1.1.1 Overview. Review of the following site characteristics shall be conducted by each BWR facility in locating the gaseous and/or liquid hydrogen supply systems: • Location of supply system in proximity to exposures as addressed in NFPA 50A and 50B. • Route of hydrogen delivery on site. • Location of supply system in proximity to safety-related equipment.	4.1.1.1 Comply:
4.1.1.2 Specific Considerations.	
4.1.1.2.1 Fire Protection. The area selected for hydrogen system siting shall meet or exceed all requirements for protection of personnel and equipment as addressed in NFPA 50A and 50B, gaseous and liquified hydrogen systems, respectively. Each standard identifies the maximum quantity of hydrogen storage permitted and the minimum distance from hydrogen systems to a number of exposures.	**4.1.1.2.1 (Paragraph 1) Comply with intent:** Paragraph 3-1.2 of NFPA 50A-1984 requires that gaseous hydrogen systems shall be located above ground. The gaseous supply vessel is located above ground but the piping from the supply facility to the turbine building is below ground. This is considered acceptable as the piping is routed above ground prior to entering the turbine building.
The need for additional fire protection for other than the hydrogen facility shall be determined by analysis of local conditions of hazards onsite, exposure to other properties, water supplies, and the probable effectiveness of plant fire brigades in accordance with NFPA 50A and 50B.	**4.1.1.2.1 (Paragraph 2) Comply:**
4.1.1.2.2 Security. All hydrogen storage system installations shall be completely fenced, even when located within the owner-controlled area. Lighting shall be installed to facilitate night surveillance.	**4.1.1.2.2 Comply:**

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
4.1.1.2.3 Route of Hydrogen Delivery on Site. Each plant should determine the route to be taken by hydrogen delivery trucks through onsite and offsite areas. In order to protect the hydrogen storage area from any vehicular accidents, truck barriers shall be installed around the perimeter of the system installation. Within the plant security area, all deliveries shall be controlled per the requirements of 10 CFR 73.55.	**4.1.1.2.3 Comply:**
4.1.1.2.4 Location of Storage System to Safety-Related Structures. Each plant shall determine that the location of the hydrogen storage system is acceptable relative to safety-related structures and equipment considering the hazards described in Sections 4.1.2, 4.1.3, 4.2.1, and 4.2.2.	**4.1.1.2.4 Comply:** The hydrogen storage area is 1500 feet south of the nearest safety-related structure, which is the Unit 1 and 2 control room.
4.1.2 Gaseous Storage Vessel Failure Gaseous storage vessels in the scope of this report are the commercially available, seamless, swagged-ended vessels that are commonly referred to as "hydril tubes." This section addresses the nonmechanistic rupture failure of single vessels and the separation distances required to avoid damage to safety-related equipment. Simultaneous failure of multiple vessels is not addressed because the inherent strength of the vessel makes them unsusceptible to failure from outside forces. These vessels shall be capable of withstanding tornado missiles (NUREG-0800) and site specific seismic loading due to horizontal and vertical accelerations acting simultaneously. These features eliminate common cause vessel failures so that the maximum postulated instantaneous release is the fully pressurized contents of the largest single vessel. The potential consequences of such a release, a fireball or an explosion, are addressed in order.	**4.1.2 Comply:**

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
4.1.2.1 Fireball. The thermal flux versus distance from the fireball center are shown on Figure 4-1 for the two most common vessel sizes. These fluxes and durations will not adversely affect safety-related structures. However, each utility shall review any unique site characteristics to assure all safety-related equipment will function in the event of a fireball.	4.1.2.1 Comply:
4.1.2.2 Explosion. When a gaseous storage vessels ruptures, the expansion of the high-pressure gas results in rapid turbulent mixing with the surrounding air. In the case of gaseous hydrogen, the release will go through the detonation limits of 18.3 - 59% before the wind can translate the mixture. Consequently, any explosion blastwaves will originate at the vessel rupture site. For this report, it is conservatively assumed that 100% of the vessel contents will contribute to the blastwave and that the TNT-hydrogen equivalence is 20% on an energy basis (520% on a mass basis). This translates to 27.1 lbs of TNT per 1000 standard cubic feet (SCF) of gaseous hydrogen. Using this conversion factor and U.S. Army Technical Manual TM5-1300, blast overpressures and impulses can be calculated as functions of distance from the vessel location. These blast parameters could then be compared to the dynamic strength of safety-related structures.	4.1.2.2 Comply:
An evaluation entitled "Separation Distances Recommended for Hydrogen Storage to Prevent Damage to Nuclear Power Plant Structures From Hydrogen Explosion" was performed for EPRI by R. P. Kennedy. This evaluation, which is included as Appendix B of these guidelines, recommends separation distances based on quantities of stored hydrogen and building design factors. The recommendations are provided in the form of step-by-step procedures, with subsequent steps requiring additional work but resulting in	

reduced distances from the previous step. The procedure to determine acceptable separation distances is outlined below.

- **Step 1.** For any reinforced concrete or masonry walls at least 8 inches thick, the upper curve on Figure 4-2 provides conservative separation distances as a function of vessel size. If this is acceptable, then no further work is needed. Otherwise, proceed to step 2.
- **Step 2.** For reinforced concrete walls at least 18 inches thick, with known static strength and percent tensile rebar, Eq. 7 in Appendix B can be used to determine required separation distances. The two lower curves on Figure 4-2 are representative examples of design parameters for walls of nuclear power plants. Walls with different parameters should be analyzed using the methods in Appendix B, pages 10 through 13. If this is acceptable, then no further work is needed. Otherwise, proceed to step 3.
- **Step 3.** For separation distances closer than allowed by the above 1 and 2, perform a dynamic blast capacity analysis in accordance with NUREG/CR-2462 (1).

For all storage locations, the vessel(s) and the foundation(s) shall be designed to remain in place for both design-basis tornado characteristics and site-specific flood conditions.

4.1.3 Gaseous Pipe Breaks

4.1.3 Comply:

This section addresses the requirements for hydrogen piping systems attached to gaseous storage vessels up to the point where excess flow protection is provided. The criteria for acceptable siting for the event of a pipe break are:

- Dilution of resultant release below the lower flammability limit of 4% before reaching air pathways into safety-related structures.
- Minimum separate distances for the blast damage criteria outlined in Section 4.1.2.

It is conservatively assumed that all releases occur while the storage vessel is at 2,450 psig. This is the maximum allowable working pressure of the majority of commercially available vessels.

Gaseous releases at elevated pressures result in supersonic jet velocities and a dispersion process that is momentum-dominated. Under these conditions, the Gaussian dispersion model unrealistically overestimates the amount of hydrogen in the explosive region and the distance to the lower flammable region. Therefore, these properties of gaseous releases were calculated using a jet dispersion model described in Reference (2).

The results of this modeling are shown in Figure 4-3 as minimum separation distances versus inside diameter of the pipe. The upper curve is the maximum distance to the lower flammability limit of 4% hydrogen. Each utility shall determine that the location of air pathways into safety-related structures exceeds this minimum separation distance or show that other criteria should be applied to a specific case. An example of such an exception would be if the air intakes have automatic shutters controlled by hydrogen analyzers thus preventing the ingestion of a flammable mixture.

The lower curve on Figure 4-3 is the minimum required distance to safety-related structures with greater than or equal to an 8-inch-thick reinforced masonry or concrete wall. This distance includes the drift distance of an unignited, fully developed gaseous jet plus the blast distance

4.1.3 (Continued) Comply:

foundation design at each installation shall meet these requirements.

Design basis tornado-generated missiles are capable of breaching all known commercially available liquid hydrogen storage vessels. Therefore, tornado missiles are a potential cause of "storage vessel failure."

- Aircraft

  A large aircraft crashing directly into the storage area is capable of breaching all known commercially available liquid hydrogen storage vessels. Therefore, aircraft crash is a potential cause of "storage vessel failure."

- Fire

  The overpressure protection system shall be sized to accommodate the worst-case vaporization rate caused by a hydrocarbon fire engulfing the outer shell with loss of vacuum and hydrogen in the annulus of the double-wall storage tank (as per Compressed Gas Association 5.3 and ASME Section VIII requirements).

- Flood

  The following flood conditions could result in vessel failure:

  -- High water reaches the top of the vent stack for the overpressure protection system.

  -- High flood velocities dislodge the tank.

  Under either condition, water could enter the vent system and defeat the overpressure protection system. Therefore, the tank shall be located such that maximum flood heights cannot exceed the vent stack

4.2.1 (Continued) Comply:

elevation and such that potential flood velocities cannot damage the vent stack or dislodge the tank.

4.2.1 (Continued) Comply:

- Vehicle Impact

  The storage vessel shall be protected from the impact of the largest vehicle used onsite by a barricade capable of stopping such a vehicle.

- Vessel Structural Failure

  The storage vessel shall be designed, constructed, inspected and operated to assure an extremely low likelihood of tank structural failure during its tenure on site. A vessel designed in accordance with this document complies with this low-probability requirement.

4.2.1.1 Fireball

4.2.1.1 Comply:

For the two potential causes of "storage vessel failure," tornado missiles and aircraft impact, a fireball at the tank location is the expected result. The major reasons for this is the high ignitability of hydrogen and the density of ignition sources in the aftermath of these casual events. An aircraft impact or a design basis tornado and the associated missiles will also provide numerous sources of ignition from downed power lines, damaged transformers, and switchgears, etc. Details of these considerations are given in the report for the Dresden plant (2).

The thermal flux versus distance from the fireball center (tank location) is shown on Figure 4-4 for the range of commercially available tank sizes. The durations of the various fireball sizes are also given. These fluxes and durations will not adversely affect equipment or personnel enclosed in concrete/steel safety-related structures. However, each utility shall for the maximum amount of hydrogen in the detonable region. It conservatively assumes that the pipe break is oriented directly toward the safety-related structures. Each utility shall determine compliance with this minimum separation distance or demonstrate that other criteria should be applied.

4.2 LIQUID HYDROGEN

4.2.1 Storage Vessel Failure

For this report, storage vessel failure is defined as a large breach resulting in the rapid emptying of the entire contents of liquid hydrogen. It is assumed that the tank is full at the time of failure and that the entire spill vaporizes instantaneously. The following enumerates potential causes of vessel failure and the required design features that mitigate or alleviate these potentials.

- Seismic

  The tank and its foundation shall be designed to meet the seismic criterion for critical structures and equipment at the plant site (i.e., design basis earthquake). It is preferable to seismically support all liquid hydrogen piping. If this is not possible, the liquid hydrogen piping shall be seismically supported up to and including excess flow protection devices. The specific liquid hydrogen tank and piping design at each installation shall meet these requirements.

- Tornado and Tornado Missiles

  The tank and its foundation shall be designed to withstand the "design basis tornado characteristics" as outlined in Regulatory Guide 1.76. As a minimum, the tank shall remain in place so that any liquid spillage will originate from the tank location. The specific tank and

4.2 Comply:

4.2.1 Comply:

review any unique site characteristics to assure all safety-related equipment will function in the event of a fireball.

4.2.1.2 Explosion at Tank Site

Although an explosion is not expected, safety-related structures and equipment shall be verified to be capable of withstanding a detonation occurring at the site of the tank installation. For the instantaneous release of the entire tank contents, the following were used to determine blast parameters for an explosion at the tank site:

1. Gaussian F weather stability
2. Detonation limits of hydrogen, 18.3-59%
3. TNT - hydrogen equivalent of 20% on an energy basis (520% on a mass basis)

NUREG/CR-2726 reports that detonations have been observed for hydrogen concentrations as low as 13.8% when ignited in a long, large-diameter tube. The explosive yield or TNT equivalence of such threshold concentration reactions is extremely low because most of the combustion energy is expended in the transition to detonation. This is essentially the reason why it represents the lower detonation limit; any less concentration will give a zero detonation yield. This also points out that both hydrogen concentration and explosive yield affect the total equivalent mass of TNT for a given release.

Regulatory Guide 1.91 models the blast effects from transportation accidents by assuming 100% of the cargo detonates at a TNT mass equivalence of 240% (one pound of cargo equals 2.4 pounds of TNT). The analysis described in this report modeled large spills of hydrogen by calculating the amount of release that is between 18.3 and 59% (~46% of the vessel contents) and assuming that it detonates at a TNT mass

4.2.1.2 Comply:

equivalence of 520%. The resulting TNT equivalence for this method is one pound of vessel contents equals 2.4 pounds of TNT, an identical result to that obtained with the NRC method.

The above results in an equivalence of 1.37 lbs of TNT per gallon of tank size. Using this conversion factor and U.S. Army Technical Manual TM5-1300 and the damage criteria outlined in Appendix B, required separation distances have been determined as a function of tank size. The results are shown on Figure 4-5 for the design parameters of the three building types described in Section 4.1.2.2. For buildings with other design parameters, the methods in Appendix B or in NUREG/CR-2462 (1) may be used to determine separation distances. Each utility shall use these methods for determining the minimum required separation distances from the storage tank to safety-related structures or equipment for the event of an explosion at the tank site.

4.2.2 Pipe Breaks

This section addresses the requirements for gaseous and liquid hydrogen piping systems attached to the storage vessel up to the point where excess flow protection is provided. The criteria for acceptable siting for the event of a pipe break are the same as outlined in Section 4.1.3. It is conservatively assumed that all releases occur while the storage vessel is at 150 psig (the maximum allowable working pressure of the majority of commercially available tanks).

4.2.2 Comply:

4.2.2.1 Gaseous Piping

The same dispersion model for momentum-dominated jets discussed in Section 4.1.3 applies to gaseous releases from liquid storage tank piping with the appropriate release conditions for saturated vapors. The results of this modeling are shown in Figure 4-6 as

4.2.2.1 Comply:

minimum separation distances versus hole size or inside diameter of piping not protected with excess flow devices. The upper curve is the maximum drift distance to the lower flammability limit and is the minimum required separation distance to air pathways into safety-related structures. The three lower curves are required separation distances for the representative types of safety-related structures. These distances are the sum of both the drift and blast distances. Structures with other parameters can be analyzed using the methods in Appendix B or in NUREG/CR-2462 (1). Each utility shall determine that the storage vessel piping and location meet these minimum requirements or show that less stringent criteria should be applied to a specific case. An example of such a suitable exception would be if the air intakes are provided with automatic shutters controlled by hydrogen analyzers to prevent the ingestion of a flammable mixture.

4.2.2.2 Liquid Piping

The vapor cloud formed by the flashing and rapid vaporization of a liquid release is nearly neutrally buoyant and has little momentum associated with its formation. For these conditions, a Gaussian dispersion model is employed using the following conservative assumptions:

1. Instantaneous vaporization of release
2. F weather stability
3. 1 m/s wind speed
4. Wind direction towards safety-related area

No credit is to be taken for site-specific wind direction or speed characteristics since it is assumed that pipe breaks can occur during the worst-case weather and wind conditions.

4.2.2.2 Comply:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
The minimum required separation distances for liquid hydrogen pipe breaks, using the above assumptions, are given on Figure 4-7 as a function of discharge rate and hole size. The upper curve is the drift distance to the lower flammability limit for a fully developed could with F stability and 1 m/s windspeed. This defines the minimum required separation distance to air pathways into safety-related structures. The three lower curves define the minimum required separation distances to the representative safety-related structures. These curves include the drift distance to the center of the detonable cloud and the blast distance for the amount of hydrogen in the detonable region. For other structure types, Appendix B or NUREG/CR-2462 (1) may be used to determine blast distances. These distances shall be applied to all liquid piping, including those from any pump discharges, that are not seismically supported or protected by excess flow devices.	
4.3 ELECTROLYTIC	**4.3 Not applicable:** Electrolytic hydrogen production is not being used at this time.
4.4 LIQUID OXYGEN	
4.4.1 <u>Site Characteristics of Liquid Oxygen</u>	
4.4.1.1 Overview. Review of the following site characteristics shall be completed by each BWR facility as part of their efforts to locate the liquid oxygen storage system. - Location of supply in proximity to exposure as addressed in NFPA 50. - Route of liquid oxygen delivery on site.	4.4.1.1 Comply:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
• Location of supply system in proximity to safety-related equipment.	
• Location of hydrogen storage.	
4.4.1.2 Specific Considerations.	
4.4.1.2.1 **Fire Protection.** The area selected for liquid oxygen system siting shall meet or exceed all requirements for protection of personnel and equipment as addressed in NFPA 50, Bulk Oxygen Systems. The standard identifies the types of exposures under consideration. The number of exposures warrants a plant-specific review for proper code compliance. As much separation distance as practical should be provided between the hydrogen and oxygen systems.	**4.4.1.2.1 Comply:**
4.4.1.2.2 **Security.** All liquid oxygen supply system installations shall be completely fenced, even when located within the security area. Lighting shall be installed to facilitate night surveillance.	**4.4.1.2.2 Comply:**
4.4.1.2.3 Route of Liquid Oxygen Delivery on Site. Each plant should determine the route to be taken by liquid oxygen delivery trucks through on- and offsite areas. In order to protect the oxygen storage area from any vehicular accidents, truck barriers shall be installed around the perimeter of the system installation. Within the plant security area all deliveries shall be controlled by plant security personnel, per the requirements of 10 CFR 73.55.	4.4.1.2.3 Comply:
4.4.1.2.4 **Location of Storage System to Safety-Related Equipment.** Each plant shall determine that the location of the liquid oxygen supply system is acceptable considering the hazard described in Sections 4.4.2 and 4.4.3.	**4.4.1.2.4 Comply:** The oxygen storage area is located 1000 feet south of the nearest safety-related structure, which is the Unit 1 and 2 control room.

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
4.4.2 Liquid Oxygen Storage Vessel Failure Liquid oxygen storage vessels are vulnerable to the same potential causes of failure as the liquid hydrogen vessels but the potential consequences of failure are much less severe. The potential threat from a liquid oxygen spill is the contact of oxygen-enriched air with combustible materials or the ingestion of oxygen-enriched air into safety-related air intakes. Additional information on the effects of oxygen-enriched atmospheres is given in NFPA 53M and in ASTM G63-83a and G88-84. For the purpose of this report, it is conservatively assumed that total oxygen concentrations above 30 vol% (21% O_2 in air + 9% enriched O_2) will increase the effective combustibility of ignitible materials in the area.	4.4.2 Comply:
4.4.3 Liquid Oxygen Vapor Cloud Dispersion The vapor cloud instantaneously formed by a large liquid oxygen spill will have a density of 3.59 relative to air. Such a cloud will experience considerable gravity-driven slumping as it disperses and translates with the wind. This process has been described by the DEGADIS model developed by Prof. J. A. Havens of the University of Arkansas (3). His model has been found to agree well with published data on large releases of dense gases conducted by the U.S. Department of Energy, U.S. Coast Guard and others. The DEGADIS model has been used to determine the height of the vapor cloud as a function of distance for various sizes of commercially available liquid oxygen storage tanks. It was conservatively assumed that any vessel failure would result in the instantaneous vaporization of the entire tank contents. The curves on Figure 4-8, which define "acceptable location of safety-related air intake," were generated by using the DEGADIS model under the worst-case weather conditions of F	4.4.3 Comply:

stability and 10 m/s wind speed for total oxygen concentrations of 30 vol%. For dense gas dispersion, lower wind speeds result in more radial spreading with a lower cloud height and shorter maximum drift distance. Higher wind speeds will translate even the largest release past safety-related intakes in less than 10 sec, giving little time for ingestion of enriched air.

Therefore, liquid oxygen storage vessels shall be located such that safety-related air intakes are within the acceptable region defined by Figure 4-8 or alternative analyses shall be performed to justify the location. Since this figure assumes the origin of release is from the storage location, the tank and its foundation shall be designed to remain in place for both design basis tornadoes and site specific flood conditions.

4.5 REFERENCES

1. R. P. Kennedy, T. E. Blejwas, and D. E. Bennett. "Capacity of Nuclear Power Plant Structures to Resist Blast Loadings." NUREG/CR-2462. Sandia National Laboratories for U.S. Nuclear Regulatory Commission.
2. "Air Products Liquid Hydrogen Storage System Hazardous Consequence Analysis." Revision 1, October 1, 1985.
3. J. A. Havens. "The Atmospheric Dispersion of Heavy Gases: An Update." IChemE Symposium Series No. 93, 1985.

4.5 Not applicable:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
5.0 VERIFICATION	**5.0 Comply:**
The various methods of verifying the effectiveness of HWC (i.e., electrochemical potential, constant extension rate tests, etc.) are not within the scope of this document. Appropriate methods of verification should be selected and implemented on a plant-specific basis.	A Hydrogen Water Chemistry Verification System (HWCVS) has been chosen to verify the effectiveness of the HWC system.

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
6.0 OPERATION, MAINTENANCE, AND TRAINING This section give recommendations to the operating utility for operation, maintenance, and training in order to meet the design intent of the hydrogen water chemistry (HWC) system. The operation of a HWC system will require operator and chemistry personnel attention. Because of the radiation increases that result from employing this system, an awareness of ALARA principles is required by all plant personnel. This system could also have an effect on the off-gas system and the plant fire protection program.	**6.0 Comply with intent:** Design guidance provided in this section does not include any requirements.
6.1 OPERATING PROCEDURES Written procedures describing proper valving alignment and sequence for any anticipated operation should be provided for each major component and system process. Check-off lists should be developed and used for complex or infrequent modes of operation. Operating procedures should be considered for the following operations: • Hydrogen addition system startup, normal operation, shutdown and alarm response. • Material (gas or liquid) handling (filling of storage tanks) operations that are consistent with the supplier's recommendations. • Purging of hydrogen and oxygen lines. • Operation of onsite gas generation system (if appropriate). • Fire protection or safety measures for hydrogen- or oxygen-enhanced fires and hydrogen or oxygen spills.	**6.1 Comply with intent:** All necessary procedures for safe operation and maintenance of the HWC system will be provided, and will be incorporated into existing plant procedures if possible.

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
• Calibration and maintenance procedures as recommended by equipment or gas suppliers. • Routine inspection of HWC system equipment. • Adjustment of the main steamline radiation monitor setpoints (if appropriate).	
6.1.1 Integration Into Existing Plant Operation Procedures Where appropriate, operation of the HWC system shall be incorporated into normal plant procedures such as plant startup and shutdown.	**6.1.1 Comply:**
6.1.2 Plant-Specific Procedures Appropriate procedures shall be developed to provide guidance for plant operators when operation of the HWC system necessitates operation of an existing system in a different mode or raises new concerns. Areas which should be considered are: • Operation of the off-gas system • Possible off-gas fires	**6.1.2 Comply:**
6.1.3 Radiation Protection Program Operation of an HWC system results in an increase in radiation levels wherever nuclear steam is present. The radiation protection program shall be reviewed and appropriate changes made to compensate for these increased radiation levels. The following guidelines are established to ensure that radiological exposures to both plant personnel and the general public and consistent with ALARA requirements. Compliance with these requirements minimizes radiologically significant hazards associated with HWC implementation. The operation of a hydrogen addition system may cause a slight reduction in the off-gas delay time due to the increase in	**6.1.3 Comply:**

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
the flow rate of noncondensables resulting from the excess oxygen added. This may slightly increase plant effluents and should be reviewed on a plant-specific basis.	
6.1.3.1 ALARA Commitment. Permanent hydrogen water chemistry systems and programs will be designed, installed, operated, and maintained in accordance with the provisions of Regulatory Guides 8.8 and 8.10 to assure that occupational radiation exposures and doses to the general public will be "as low as reasonably achievable."	6.1.3.1 Comply:
6.1.3.2 Initial Radiological Survey. A comprehensive radiological survey should be performed with hydrogen injection to quantify the impact of hydrogen water chemistry on the environs' dose rates, both within and outside the plant. This survey should be used to determine if significant radiation changes occur within the plant and at the site boundary. Based upon the magnitude of the change, it should be determined if new radiation areas or high radiation areas need to be created. Appropriate posting, access, and monitoring requirements should be implemented for the affected areas. Plant operating and surveillance procedures should be revised, as required, to minimize the time and number of personnel required in radiation areas for operations, maintenance, in-service inspection, etc.	6.1.3.2 Comply:
6.1.3.3 Plant Shielding. The radiological survey of Subsection 6.1.3.2 should be used to determine the adequacy of existing plant shielding. In addition, the radiation levels from sample lines, sample coolers and monitoring equipment may increase due to HWC and should be checked for adequate shielding. If required, measures for selective upgrading of plant shielding should be implemented to reduce both work area and site boundary dose rates.	6.1.3.3 Comply:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
6.1.3.4 Maintenance Activities. Hydrogen water chemistry will have minimum impact on occupational exposures resulting from maintenance activities. Plant procedures should incorporate appropriate requirements for access to and monitoring of areas where increased dose rates exist with HWC to satisfy ALARA requirements. For extended maintenance, plant procedures should include provisions to terminate the hydrogen injection. Due to the short half-life of N-16, radiation levels will return to pre-HWC conditions within minutes of hydrogen shutoff.	6.1.3.4 Comply:
6.1.3.5 Radiological Surveillance Programs. Dose rate surveys should be conducted and radiation levels should be monitored periodically to ensure compliance with the radiological limits imposed by 40 CFR Part 190, 10 CFR Part 100, and 10 CFR Part 20. Additional surveys may be required to comply with ALARA requirements. Hydrogen water chemistry, in association with improved water quantity operational practices, could affect the crud buildup within the recirculation piping and the shutdown dose rates. A radiological surveillance program should be established to monitor shutdown dose rates and crud buildup over a number of fuel cycles to evaluate possible changes.	6.1.3.5 Comply:
6.1.3.6 Measurement of N-16 Radiation. The radiological surveillance program should include provisions for the new distribution of N-16 in the main steam. Selection of appropriate health physics instrumentation and application of correction factors are required to provide accurate dose measurements. (This correction is required due to the effect of the energetic N-16 gamma on instrumentation calibrated with less energetic gamma sources.) All plant survey meters should be reviewed and appropriate calibration and correction methods accounted for in plant procedures.	6.1.3.6 Comply:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
A review of the plant personnel dosimetry program shall be conducted to ensure that the appropriate calibration or correction factors are used.	
6.1.3.7 Value/Impact Considerations. The following discussion reviews the total dose impact on a plant which implements HWC. A radiological assessment at Dresden indicates that the total dose increase with HWC is approximately 0.5% on an annual basis (from 1935 to 1945 man-rem/year) (1). While this increase is site dependent due to plant layout and shielding configurations, significant variances from the Dresden assessment are not anticipated. Thus, over the life of a plant (assuming a 25-year remaining life), the projected total dose increase with HWC is ~ 250-300 man-rems. With HWC implementation, the potential exists to relax current augmented inservice inspection requirements imposed by NRC Generic Letter 84-11 (2) and elimination of extended plant outages for pipe replacement and/or repair. The value/impact assessment presented in Appendix E to Reference 3 projects a 1161 man-rem (best estimate) savings over the life of the plant as a consequence of reduced inspections and repairs with HWC. Typical pipe replacement projects result in a total dose of 1400 to 2000 man-rems. Thus, HWC implementation could result in a significant savings in total dose over the life of the plant.	6.1.3.7 Not applicable: No design guidance is stated in this section.
6.1.4 Water Chemistry Control Procedures should be developed to maintain the high reactor water quality necessary to obtain the maximum benefit from the HWC system. Intergranular stress corrosion cracking can be mitigated by controlling the ionic impurity content of the primary coolant and by reducing the dissolved oxygen level in the primary coolant by use of HWC. The EPRI-BWR	**6.1.4 Comply:**

Owners Group has developed "BWR Hydrogen Water Chemistry Guidelines" (4), which must be met in order to obtain the full benefits of HWC. These water chemistry guidelines should be used as a basis for developing a plant-specific water chemistry control program.

Hydrogen water chemistry can reduce the dissolved oxygen level in the condensate and feedwater. It has been shown that at very low levels of dissolved oxygen, corrosion and metal transport to the primary system would be increased. If, when operating on HWC, the dissolved oxygen concentration drops below 20 ppb, an evaluation should be made to determine if there is increased corrosion or metals transport, or if other factors relating to such a reduced oxygen concentration need to be considered. If this evaluation determines that oxygen injection is necessary, a system should be designed using the guidance provided in Sections 2.3.2 and 3.4 of this report.

6.1.5 Fuel Surveillance Program

No significant effect of hydrogen injection on fuel performance has been observed, nor is expected. However, since in-reactor experience with hydrogen water chemistry is limited, utilities should consider the fuel surveillance programs recommended by their fuel suppliers.

6.1.5 Comply:

6.2 MAINTENANCE

A preventative maintenance program should be developed and instituted to ensure proper equipment performance to reduce unscheduled repairs. All maintenance activities should be carefully planned to reduce interference with station operation, assure industrial safety, and minimize maintenance personnel exposure. Written procedures should be developed and followed in the performance of maintenance work. They should be written with the objective of protecting plant personnel from physical harm

6.2 Comply:

and radiation exposure, and of reducing hydrogen addition system downtime. Radiation exposure should be reduced by shortening the time required in a high radiation field and by reducing its intensity by turning off the HWC system or other means during the maintenance period.

All excess flow check valves used for hydrogen line break protection shall be periodically tested to assure they will function properly.

6.3 TRAINING

In order for the HWC system to maintain its system integrity and to provide the expected benefits from its use, the system must be operated correctly. The most effective means of reducing the potential of operator error is through proper training.

Training should be provided to:

- Instruct operators on the function, theory and operating characteristics of the system and all its major system components.
- Advise operators of the consequences of component malfunctions and misoperation and provide instruction as to appropriate corrective actions to be taken.
- Advise operations and maintenance personnel of the potential hazards of gases in the system, and provide instruction as to appropriate procedures for their handling.
- Instruct emergency response personnel on appropriate procedures for handling fires or personnel injuries involving spills or releases of H_2 or O_2 liquid and gases.

6.3 Comply:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
• Instruct plant personnel on the expected radiation changes due to the operation of the HWC system and the appropriate ALARA practices to be taken to minimize dose. • Instruct appropriate personnel on the benefits of HWC. • Advise maintenance and construction personnel of the routing of hydrogen lines and of the appropriate protective actions to be taken when working near these lines. Periodic training should be provided to reinforce information described above and to communicate information regarding any modifications, procedural changes, or incidents.	
6.4 IDENTIFICATION In order to aid plant personnel in identifying hydrogen and oxygen lines, these lines should be color coded as required by ANSI A13.1.	**6.4 Do not comply:** See Section 10.1 of the HWC licensing package for justification for noncompliance.
6.5 REFERENCES 1. "Environmental Impact of Hydrogen Water Chemistry." EPRI Hydrogen Water Chemistry Workshop, Atlanta, Georgia, December 1984. 2. "Inspection of BWR Stainless Steel Piping." NRC Generic Letter 84-11, April 19, 1984. 3. "Report of the United States Nuclear Regulatory Commission Piping Review Committee." NUREG-1061, Volume 1, August 1984. 4. <u>BWR Hydrogen Water Chemistry Guidelines: 1987 Revision. NP-4947-SR-LD.</u> Palo Alto, Calif.: Electric Power Research Institute, to be published.	**6.5 Not applicable:**

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
7.0 SURVEILLANCE AND TESTING	
7.1 SYSTEM INTEGRITY TESTING In addition to the testing required by the applicable design codes, completed process systems which will contain hydrogen shall be leak tested with helium or a soap solution as appropriate prior to initial operation of the system. All components and joints shall be so tested in the fabrication shop or after installation, as appropriate. Appropriate helium leak tests shall be performed on portions of the system following any modifications or maintenance activity which could affect the pressure boundary of the system.	**7.1 Do not comply:** See Section 10.3 of the HWC licensing package for justification for nonconformance.
7.2 PREOPERATIONAL AND PERIODIC TESTING Completed systems should be tested to the extent practicable to verify the operability and functional performance of the system. Proper functioning of the following items should be verified: • Trip and alarm functions per Table 2-2. • Gas purity, if generated on site. • Safety features. • Excess flow check valves. • System controls and monitors per Table 2-2. A program should be developed for periodic retesting to verify the operability and the functional performance of the system.	**7.2 Comply:**

8.0 RADIATION MONITORING

8.1 INTRODUCTION

This section reviews the radiological consequence of hydrogen water chemistry (HWC) and presents the basis for increasing the main steamline radiation monitor setpoint to accommodate HWC. It is concluded that implementation of HWC does not reduce the margin of safety as defined in the basis of the technical specification setpoint.

During normal operation of a BWR, nitrogen-16 is formed from an oxygen-16 (N-P) reaction. N-16 decays with a half-life of 7.1 sec. and emits a high-energy gamma photon (6.1 MeV). Normally, most of the N-16 combines rapidly with oxygen to form water-soluble, nonvolatile nitrates and nitrites. However, because of the lower oxidizing potential present in a hydrogen water chemistry environment, a higher percentage of the N-16 is converted to more volatile species. As a consequence, the steam activity during hydrogen addition can increase up to a factor of approximately five. The dose rates in the turbine building, plant environs, and off site also increase; however, the magnitude of the increase at any given location depends upon the contribution of the steam activity to the total dose rate at that location. The specific concerns include:

- The dose to members of the general public (40 CFR 190),
- The dose to personnel in unrestricted areas (10 CFR 20), and
- The maintenance of personnel exposure "as low as reasonably achievable" (ALARA).

8.1 Comply with intent:

Design guidance provided in this section does not include any requirements.

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
8.2 MAIN STEAMLINE RADIATION MONITORING As noted in the previous section, main steamline radiation levels can increase up to approximately fivefold with hydrogen water chemistry. The majority of BWRs have a technical specification requirement for the main steamline radiation monitor (MSLRM) setpoint that is less than or equal to three (3) times the normal rated full-power background. For these plants an adjustment in the MSLRM setpoint may be required to allow operation with hydrogen injection. For earlier BWRs with MSLRM setpoints of seven (7) to ten (10) times normal full-power background, a setpoint change may not be required.	**8.2 Do not comply:** See Section 8.2 and 10.4 of the HWC licensing package for justification for nonconformance.
8.2.1 Dual MSLRM Setpoint Recommendation For plants at which credit is taken for an MSLRM-initiated isolation in the control rod drop accident (CRDA), a dual setpoint approach may be utilized. At most plants, the MSLRM setpoint is specified in the plant Technical Specifications (Tech Specs) as some factor times rated full-power radiation background. With hydrogen addition, the full-power background could increase up to 5 times that without hydrogen addition. Below 20% rated power or the power level required by FSAR or Tech Specs (see Table 2-1), the existing setpoint is maintained at the Tech Spec factor above normal full-power background, and hydrogen should not be injected. About 20% rated power, the MSLRM setpoint should be readjusted to the same Tech Spec factor above the rated full-power background with hydrogen addition. This adjustment would be made by the plant personnel during startups and shutdowns. Plant power would remain constant during this adjustment process. Thus, the Tech Spec factor which the MSLRM setpoint is adjusted remains the same with and without hydrogen addition, but the background radiation level increases with hydrogen addition. If an	**8.2.1 Do not comply:** See Section 8.2.

unanticipated power reduction event occurs such that the reactor power is below this power level without the required setpoint change, control rod motion should be suspended until the necessary setpoint adjustment is made. At newer plants, credit is not taken for an MSLRM-initiated isolation after a CRDA, and a dual setpoint is not needed at these plants.

Plants that need a dual setpoint should consider changing their Technical Specifications to increase the factor used to determine the MSLRM setpoint, if their CRDA analysis will permit this increase. A suggested approach would be to use the Susquehanna Steam Electric Station, Unit 1, Amendment No. 58 Technical Specification change as a model. Under this approach, the MSLRM setpoint was raised based on a satisfactory evaluation of the offsite consequences.

8.2.2 MSLRM Safety Design Basis

The only design basis event for which some plants may take credit for main steam isolation valve (MSIV) closure on main steamline high radiation is the design basis control rod drop accident (CRDA). As documented in Reference (1), the CRDA is only of concern below 10% of rated power. Above this power level the rod worths and resultant CRDA peak fuel enthalpies are not limiting due to core voids and faster Doppler feedback. Since the current MSLRM setpoint will not be changed below 20% rated power, the MSLRM sensitivity to fuel failure is not impacted and the FSAR analysis for the CRDA remains valid.

The licensing basis for the CRDA states that the maximum control rod worth is established by assuming the worst single inadvertent operator error (2). From References (2) and (3), the maximum control rod worth above 20% rated power, assuming a single operator error, is $<0.8\%$ $\Delta K/K$. Parametric studies utilizing the

8.2.2 Do not comply:

See Section 8.2.

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
conservative GE excursion model (1) indicate that the maximum peak fuel enthalpy for a dropped control rod worth of 0.8% ΔK/K is less than 120 calories per gram (3). Consequently, the conservatively calculated peak fuel enthalpy for a CRDA above 20% rated power will have significant margin to the fuel cladding failure threshold of 170 calories per gram.	
An increase in the MSLRM setpoint will not impact any other FSAR design basis accident or transient analysis since no credit is taken for this isolation signal. Consequently, a technical specification change which adopts the recommended dual setpoint approach will not reduce overall plant safety margins.	
8.2.3 MSLRM Sensitivity Conceptually, the sensitivity of the MSLRM to fission products is effectively reduced by the increase in the setpoint above 20% power. However, it is still functional and capable of initiating a reactor scram. The main function of the instrument is to help maintain offsite releases to within the applicable regulatory limits. The MSLRM is supplemented by the off-gas radiation monitoring system which monitors the gaseous effluent prior to its discharge to the environs. The off gas radiation monitor setpoint is established to help ensure that the equivalent stack release limit is not exceeded.	**8.2.3 Do not comply:** See Section 8.2.
8.2.4 Conclusions From the above discussion, it can be concluded that an increase in the MSLRM setpoint above 20% rated power will not reduce the safety margins as defined by Technical Specifications or increase the offsite radiological effects as a consequence of design base accidents. Furthermore, since this change to the MSLRM can be justified independent of HWC, this change does not constitute an unreviewed safety concern.	**8.2.4 Do not comply:** See Section 8.2.

8.3 EQUIPMENT QUALIFICATION

Outside primary containment the increase in dose rates with HWC is small relative to the integrated dose assumed for equipment qualification (EQ) tests. Furthermore, dose rates inside the drywell near the recirculation piping will decrease because of the increased carryover of N-16 in the steam. Each utility should review the resultant dose increases to ensure that the doses assumed in the EQ tests required for electrical equipment per 10 CFR Part 50.49 remain bounding.

8.3 Comply:

8.4 ENVIRONMENTAL CONSIDERATIONS

Implementation of an HWC system is unlikely to significantly increase the amounts or significantly change the types of effluents that may be released off site. Although an increase in individual or cumulative occupational radiation exposure may occur, the guidelines provided in Section 6.1.3 of this document will ensure that radiological exposures to both plant personnel and the general public are consistent with ALARA requirements. Since the design objectives and limiting conditions for operation as defined 10 CFR Part 50, Appendix I, are not impacted, no Appendix I revision is required.

Each plant should examine the environmental effects of an HWC system. However, it is unlikely that environmental impact statements or environmental assessments will be required for HWC systems.

8.4 Comply:

8.5 REFERENCES

1. R. C. Stirn, et al., "Rod Drop Analysis for Large Boiling Water Reactors." NEDO-10527. General Electric Company, March 1972.
2. R. C. Stirn, et al., "Rod Drop Accident Analysis for Large Boiling Water Reactors Addendum No. 2 Exposed Cores." NEDO-10527, Supplement 2. General Electric Company, January 1973.
3. R. C. Stirn, et al., "Rod Drop Accident Analysis for Large Boiling Water Reactors Addendum No. 1 Multiple Enrichment Cores with Axial Gadolinium." NEDO-10527, Supplement 1. General Electric Company, July 1972.

8.5 Not applicable:

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
9.0 QUALITY ASSURANCE	**9.0 Comply with intent:**
Although the HWC system is non-nuclear safety-related, the design, procurement, fabrication and construction activities shall conform to the quality assurance provisions of the codes and standards specified herein. In addition, or where not covered by the referenced codes and standards, the following quality assurance features shall be established.	Design guidance provided in this section does not include any requirements.
9.1 SYSTEM DESIGNER AND PROCURER	**9.1 Comply:**
• **Design and Procurement Document Control.** Design and procurement documents shall be independently verified for conformance to the requirements of this document by individual(s) within the design organization who are not the originators of the design and procurement documents. Changes to design and procurement documents shall be verified or controlled to maintain conformance to this document.	
• **Control of Purchased Material, Equipment and Services.** Measures shall be established to ensure that suppliers of material, equipment and construction services are capable of supplying these items to the quality specified in the procurement documents. This may be done by an evaluation or a survey of the suppliers' products and facilities.	
• **Handling, Storage, and Shipping.** Instructions shall be provided in procurement documents to control the handling, storage, shipping and preservation of material and equipment to prevent damage, deterioration, and reduction of cleanliness.	

Guidelines for Permanent BWR Hydrogen Water Chemistry Installation	Implementation or Justification for Nonconformance
9.2 CONTROL OF HYDROGEN STORAGE AND/OR GENERATION EQUIPMENT SUPPLIERS In addition to the requirements in Section 9.1, the system designer should audit the design and manufacturing documents of the equipment supplier to assure conformance to the procurement documents. The system designer shall specify specific factory tests to be performed which will assure operability of the supplier's equipment. The system designer or his representative should be present for the factory tests.	**Comply with intent:** A hydrogen supplier has not been chosen at this time. When chosen, the criteria in this section will be met.
9.3 SYSTEM CONSTRUCTOR • **Inspection.** In addition to code requirements, a program for inspection of activities affecting quality shall be established and executed by, or for, the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings for accomplishing the activity. This shall include the visual inspection of components prior to installation for conformance with procurement documents and visual inspection of items and systems following installation, cleaning, and passivation (where applied). • **Inspection, Test and Operating Status.** Measures shall be established to provide for the identification of items which have satisfactorily passed required inspections and tests. • **Identification and Corrective Action for Items for Nonconformance.** Measures shall be established to identify items of nonconformance with regard to the requirements of the procurement documents or applicable codes and standards and to identify the remedial action taken to correct such items.	**9.3 Comply:**

ATTACHMENT C

DRAFT COPY OF PROPOSED CHANGES TO
UPDATED FSAR AS A RESULT OF HWC
ADDITION AT QUAD CITIES STATION

off-gas monitoring subsystem, producing an output voltage compatible with the usual radiation level of the steam flow during plant operations. Output signals from the monitors are applied to the process computer and through selector switches to a two-pen strip-chart recorder in the control room. The selector switches select between monitors A and B for input to the red pen of the recorder, and between monitors C and D for input to the black pen of the recorder.

Each log rad monitor has a downscale alarm trip (possible circuit malfunction) and an upscale trip that is preset to a value fifteen seven times the normal background radiation. (Another upscale trip preset at a value seven and one half three times the normal background radiation annunciates a main steamline high radiation alarm on control room panel 90X-3. This alarm is activated by a switch on either two pen recorder.) The log rad monitor upscale trip (preset at fifteen seven times normal background) is connected to the reactor protection system (RPS), which has two safety channels both of which must be activated to initiate a protective action. Circuits are arranged such that an upscale trip from monitor A or C activates RPS channel A, and an upscale trip from monitor B or D activates RPS channel B. Activating either safety channel annunciates a channel A or B main steamline high radiation alarm on control room panel 90x5. Activating both channels results in a channel A and channel B main steamline high radiation alarms and initiates the following protective action:

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a. All Group I primary containment isolation valves, including the main steamline isolation valves, are closed (See subsection 7.7.2).

b. The off-gas isolation valves are closed.

c. The mechanical vacuum pump is tripped.

d. The reactor is scrammed from closure of the MSIV's.

10.17 HYDROGEN WATER CHEMISTRY SYSTEM

The purpose of the Hydrogen Water Chemistry (HWC) System is to inject hydrogen gas into the reactor coolant, via the condensate system, to suppress the dissolved oxygen concentration. This suppression of the dissolved oxygen coupled with a high purity reactor coolant will reduce the susceptibility of reactor piping and materials to intergranular stress corrosion cracking (IGSCC).

10.17.1 Design Basis

The following BWR hydrogen water chemistry points shall be maintained, during HWC system operation, to mitigate the potential for IGSCC in the reactor coolant system .

A. Dissolved oxygen concentration in the reactor coolant between 4 and 16 ppb.

B. Reactor coolant conductivity of less than 0.2 μS/cm.

10.17.2 Description

10.17.2.1 Hydrogen Injection System

The hydrogen supply site is located 1500 feet from the nearest safety-related structure, which is the Unit 1 and 2 control room, at an elevation of 633 feet. It is surrounded by a lighted security fence, and truck barrier posts are installed at the fence perimeter to protect it from mobile equipment. The hydrogen is stored as a high pressure gas in transportable tube trailers and as a liquid in a cryogenic storage tank.

The liquid hydrogen is supplied from a 20,000-gallon cryogenic storage tank. The liquid hydrogen is pumped from this storage tank to a hydrogen vaporization station. This station consists of a parallel array of ambient air vaporizers, with either of the two vaporizer legs being capable of supplying the maximum required hydrogen supply of 140 scfm for the station. After the vaporization station, the hydrogen line is connected to an isolation valve which is connected to an excess flow check valve and a nitrogen purge connection. The hydrogen pipe is then routed underground to a point within several feet of the outside of the west wall for the Unit 1 turbine building.

The gaseous hydrogen tube trailers will serve as an interim hydrogen supply system until the liquid hydrogen supply system is operational. The tube trailers will then be used as a reserve supply of hydrogen gas. The hydrogen gas flows from the tube trailer through a close-coupled shutoff valve and a parallel array of pressure reducing regulators. The trailer is connected, via a flexible pigtail, to a discharge stanchion. The discharge stanchion consists of a shutoff valve, check valve, bleed valve, and a grounding strap. After the discharge stanchion, the hydrogen line is connected to an isolation valve which is then connected to the hydrogen gas line from the liquid hydrogen supply system, upstream of the excess flow check valve.

A branch line proceeds to the Unit 1 and 2 generator hydrogen control cabinet while the main line is connected to an additional excess flow check valve, a nitrogen purge connection, and a manual isolation valve. This line then branches to the Unit 1 or Unit 2 side of the Turbine Building. Inside the building, the hydrogen line is first connected to a solenoid operated isolation valve, which closes upon an area hydrogen concentration high signal. Next, the line is connected to a parallel array of flow control stations. Each flow control station has an isolation valve and a nitrogen purge connection on each end with a flow control valve and pressure and flow instruments in between. After the flow control station the hydrogen line is connected to a purge line flame arrestor and then it branches into four lines leading to the condensate pumps. Each of these lines contain a manual isolation valve, a solenoid operated isolation valve which closes if the associated condensate pump is not activated or if the HWC system is tripped, a check valve, and a second manual isolation valve before it connects to the condensate pump discharge line.

10.17.2.2 Oxygen Injection System

The oxygen supply site is located 1000 feet from the Unit 1 and 2 control room, 500 feet from the hydrogen supply site, and at an elevation of 615 feet. It is surrounded by a lighted security fence, and truck barriers are installed at the fence perimeter to protect it from mobile equipment.

The oxygen is stored in an 11,000-gallon liquid oxygen tank. The oxygen flows from the tank into an oxygen vaporization station. This station consists of two pairs of ambient air vaporizers installed in parallel. Each pair of vaporizers can be isolated without affecting the maximum required oxygen supply of 70 scfm for the station. After the vaporizer station, the oxygen line is connected to a parallel array of pressure reducing regulators. Next, it is connected to an excess flow check valve. The oxygen pipe is then routed underground, alongside the hydrogen pipe, to a point within several feet of the outside of the west wall for the Unit 1 turbine building. After leaving the ground, the pipe branches to the Unit 1 or Unit 2 side of the turbine building. Inside the building, the oxygen piping is connected to a flow control station consisting of a flow control valve, pressure and flow instruments, and upstream and downstream manual isolation valves. The oxygen piping is finally connected to the off-gas system piping before the first stage Steam Jet Air Ejector. An additional line carrying building air is connected to an identical flow control station before being attached to the off-gas system near the oxygen injection point. This line is provided to supplement the regular oxygen supply.

10.17.2.3 Control and Instrumentation

The HWC system will supply up to 70 scfm of hydrogen to each unit's condensate system. The hydrogen addition rate can be adjusted either automatically, with the addition rate based on steam flow, or manually. The oxygen addition rate, can also be adjusted automatically, with the addition rate based on hydrogen addition rate, or manually. The oxygen injection rate is controlled to maintain a residual oxygen concentration downstream of the off-gas recombiners. Therefore, the oxygen injection system will remain operating after the hydrogen injection has been terminated, so that all free hydrogen in the off-gas system will be recombined.

System trips for the HWC System are given in Table 1 and the HWC System installed instrumentation and controls are given in Table 2.

10.17.3 Performance Analysis

The performance of the HWC System will be evaluated by the Hydrogen Water Chemistry Verification System (HWCVS). This system consists of an autoclave subsystem, an orbisphere subsystem, and a monitoring panel.

The autoclave subsystem contains three autoclaves. Each autoclave receives 2 to 4 gallons/min of water from the Reactor Building Process Sample Panel sample line at up to 1250 psig and 575°F. The first autoclave contains a crack growth monitoring system, which is capable of detecting changes in sample crack length as small as 0.0002 inch. The second autoclave is a modular unit which contains a constant extension rate tensile (CERT) test system. When installed, this system will perform a one week long CERT test on both cracked and uncracked samples. After the test has been performed the sample will be removed and examined to identify if intergranular fracture had occurred. The last autoclave contains an electrochemical potential monitoring system, which measures the corrosion potential in the water. Each of these autoclaves will provide continuous data collection. After flowing through the final autoclave, the sample water will be cooled to 150°F before being discharged to the Reactor Water Clean Up System.

The orbisphere subsystem contains a single water conductivity analyzer and two dissolved oxygen analyzers. The orbisphere subsystem receives water from the Reactor Building Process Sample Panel at 150 psig and 120°F. After passing through the orbisphere subsystem the sample water is discharged to the Reactor Process Sample Panel Drain Header for the Reactor Building Equipment Drain Tank.

The sample lines for the autoclave and orbisphere subsystems are connected to the existing Reactor Process Sample Panel Sample Line. This line passes through a pair of safety-related isolation valves before being connected to reactor recirculation loop B for Unit 1 or loop A for Unit 2.

The monitoring panel contains a computerized Data Acquisition System (DAS), which continuously monitors and records data every 20 minutes for the HWCVS in addition to plant power level, autoclave temperature and flow, and hydrogen injection rate. This system shall be used to develop correlations between crack growth and plant water chemistry parameters.

10.17.4 Inspection and Testing

The functional operability of the HWC system was tested at the time of system installation.

A preventative maintenance schedule has been incorporated into the plant maintenance program to provide surveillance inspections of the HWC System. Periodic retesting requirements for the system shall be based upon manufacturer's recommendations and in consideration of extended HWC System shutdown periods or other factors not consistent with normal system operation. Also, a retest of the hydrogen system integrity shall be performed following any modifications on the hydrogen piping which may affect the pressure boundary of the system.

The normal dose rate at the main steamline radiation (MSLR) monitors during normal full power operation is 100 mR/hr. The noble gas activity contained in each fuel rod is approximately 3.6 x 10^4 curies. Due to the decontamination effects of the primary coolant for the non-noble gas activity, the noble gas activity will be the primary dose contributor to the steamline radiation monitors in the event of fuel failure. The release of 100% of the noble gas activity in one rod would result in a detector dose rate of 1.4 R/hr to 13.8 R/hr depending on the degree of mixing in the reactor vessel. If 100% mixing is assumed, the lower dose rate of 1.4 R/hr is applicable. The set points on the MSLR monitors are adjusted to provide an alarm at ~~three~~ seven and one half times normal background (~~300~~ 750 mR/hr) and a scram signal at ~~seven~~ fifteen times normal background (~~[illegible]~~ 1500 mR/HR).

The release of that activity contained in the volume of one fuel rod, assuming 100% mixing in the reactor vessel, is therefore sufficient to result in isolation of the reactor vessel. If fuel rod damage is restricted to only the release of the plenum activity (1% of total rod activity) and conservatively assuming 100% mixing in reactor vessel vapor volume, it would require cladding failure of 89 fuel rods to isolate the reactor vessel. Under normal steam flow, fuel failure would be detected in 8.8 seconds and isolation valve closure would begin 0.5 second later with isolation valve closure being accomplished within the next 10 seconds: Therefore, the total time from fuel failure to isolation valve closure is 19.3 seconds. It should, however, be emphasized that only 10.5 seconds worth of activity will leave the reactor vessel.

Enclosure 4

APPLICATION FOR AMENDMENT
OF
FACILITY OPERATING LICENSES
DPR-29 & DPR-30

Introduction:

Commonwealth Edison Company, Licensee under Facility Operating Licenses DPR-29 and DPR-30 for the Quad-Cities Station Unit No. 1 and Unit No. 2, respectively, hereby requests that the Technical Specifications contained in Appendix A of the Operating Licenses be amended by revising the sections as indicated by a vertical bar in the margin of the attached pages 3.1/4.1-3, 3.1/4.1-8, 3.1/4.1-9, 2.1/4.1-10, 3.2/4.2-6 and 3.2/4.2-11 for Units 1 and 2. The requested change involves increasing the isolation and scram set point for the Main Steam Line Radiation Monitors from 7 times normal full power background (NFPB) to 15 times NFPB (without Hydrogen Water Chemistry). This change is being requested to support a planned Hydrogen Water Chemistry program.

Discussion:

Commonwealth Edison Company is developing a Hydrogen Water Chemistry (HWC) program to improve reactor water chemistry at Quad Cities Units 1 and 2. The purpose of the program is to reduce the effects of Intergranular Stress Corrosion Cracking (IGSCC).

Intergranular Stress Corrosion Cracking of austenitic stainless steel piping in BWRs has resulted in costly plant outages to accommodate inspections and repairs to primary coolant system piping and components. Hydrogen Water Chemistry, which consists of the combination of good water chemistry and the addition of hydrogen to the feedwater, has been shown to be effective in arresting pipe cracking and pipe crack growth. Addition of hydrogen decreases the oxidizing power of the reactor water and reduces its aggressiveness toward coolant system materials.

A by-product of the oxygen suppression by hydrogen addition is an increase in nitrogen carry-over in the main steam and an increase in radiation from the main steam lines caused by Nitrogen-16 (N-16). The increase in N-16 is promoted by the chemical change that occurs in the reactor core with hydrogen addition. The N-16 isotope is formed by a neutron-proton reaction with the Oxygen-16 (O-16) in the reactor water. Under normal chemistry conditions the majority of the N-16 forms nitrate, which is nonvolatile. With the more reducing core chemistry conditions of Hydrogen Water Chemistry, a greater fraction of the N-16 forms volatile compounds (ammonia, nitrous oxide) which are swept into the steam phase.

The revised trip setpoint will permit Hydrogen Water Chemistry implementation, while maintaining the capability to automatically isolate and scram the reactor in the event of significant fuel failures. The change will not affect the ability to detect fuel failures because the off-gas system pre-treatment radiation monitor (which is more sensitive to fuel failures than the Main Steam Line Radiation Monitor and which is not affected by this change) will retain the capability to detect fuel failures and alert the plant staff.

The proposed set point increase to 15 times NFPB (without HWC) is intended to provided operational flexibility while avoiding unnecessary scrams and the concomitant unnecessary challenges to safety systems. The factor of 15 was determined to be necessary in order to provide a margin for the increased radiation levels due to Hydrogen Water Chemistry and the design of the radiation monitors. An increase in main steam line radiation levels of as much as 5 times is possible due to Hydrogen Water Chemistry. The current setpoint of 7 provides a margin for normal meter indication fluctuation. The factor of 15 times NFPB (without HWC) was obtained by multiplying the factor of 5 by a set point margin of 3 times NFPB.

The attached Technical Specification page 3.1/4.1-3, 3.1/4.1-8, 3.1/4.1-9, 3.1/4.1-10, 3.2/4.2-6 and 3.2/4.2-11 for Units 1 and 2, indicates the proposed change involving the increase of the isolation and scram set point of the main steam line radiation monitors from 7 times NFPB to 15 times NFPB (without HWC).

Safety Assessment:

The safety function of the Main Steam Line Radiation Monitors is to detect the radiation increase in the event of a Control Rod Drop Accident (CRDA) and to close the Main Steam Isolation Valves (MSIVs) and shutdown the reactor on high radiation levels. The closure of the MSIVs reduces the release of radioactive fission products to the environment. For the CRDA, the calculated dose rate at the monitors is 8 R/hr. Because the calculated dose rate of 8 R/hr is approximately five times the proposed setpoint of 1.5 R/hr, the monitors will maintain the capability to close the MSIVs and scram the reactor on high radiation caused by the design basis Control Rod Drop Accident.

The difference between the time required for the MSLRM to reach the current trip set point (0.7 R/hr) and the new trip set point (1.5 R/hr) is approximately 1/4 second, and the time required to reach the new trip set point remains less than 1/2 second. The time period permitted for completing closure of the main steam isolation valves is 5 seconds (Quad Cities Technical Specification 3.7/4.7 D.1). The increase in time-to-closure (due to the new trip set point) is only 5% of the current time-to-closure. This will have a small effect on the total release and concomitant dose to the public. Since the calculated dose from the CRDA is only 12 mrem, the increase will be very small and, therefore, does not involve a significant increase in the consequences of an accident previously evaluated.

The capability to monitor for fuel failures is not affected by this change. The Main Steam Line Radiation Monitor's operating detection range is not changed. The Steam Jet Air Ejector Discharge Radiation Monitor, which is more sensitive to fuel failures than the Main Steam Line Radiation Monitor, is not affected by this change and will be capable of alerting the plant staff to the existence of minor fuel failures which could be present below the proposed trip setpoint.

Significant Hazards Consideration:

The proposed amendment involving the increase of the trip set point of the Main Steam Line Radiation Monitors does not represent a significant hazards consideration because operation of Quad Cities NPS with this change does not:

1. Involve a significant increase in the probability or consequences of an accident previously evaluated. The consequences of the design basis Control Rod Drop Accident, which takes credit for the operation of the Main Steam Line Radiation Monitors, are not significantly affected by this change as discussed. No other previously analyzed accidents or malfunctions, as addressed in the UFSAR, are involved.

2. Create the possibility of a new or different kind of accident from any previously evaluated. This modification only adjusts the trip set point on the Main Steam Line Radiation Monitors (MSLRM); no other station instruments or equipment are involved. The only design basis accident which takes credit for the MSLRM is the CRDA, and as discussed above, the increased set point does not affect the ability of the MSLRM to perform its intended safety function. It has also been shown that the increased set point has no affect on the capability of the station to detect noble gas releases from the reactor core.

3. Involve a significant reduction in the margin of safety. The Control Rod Drop Accident is the only accident which takes credit for the operation of the Main Steam Line Radiation Monitors. The change in the trip setpoint for the Main Steam Line Radiation Monitors does not reduce the margin between the calculated dose rate from the accident and the trip setpoint. The change does not significantly affect the consequences of the control rod drop accident as discussed above. The change offers significant benefits that enhance the margin of safety for operation with HWC by reducing the potential for inadvertent scrams and by supporting a water chemistry program which substantially mitigates IGSCC of safety-related piping.

Loss of condenser vacuum occurs when the condenser can no longer handle heat input. Loss of condenser vacuum initiates a closure of the turbine stop valves and turbine bypass valves which eliminates the heat input to the condenser. Closure of the turbine stop and bypass valves causes a pressure transient, neutron flux rise, and an increase in surface heat flux. To prevent the cladding safety limit from being exceeded if this occurs, a reactor scram occurs on turbine stop valve closure. The turbine stop valve closure scram function alone is adequate to prevent the cladding safety limit from being exceeded in the event of a turbine trip transient with bypass closure.

The condenser low-vacuum scram is a backup to the stop valve closure scram and causes a scram before the stop valves are closed, thus the resulting transient is less severe. Scram occurs at 21 inches Hg vacuum, stop valve closure occurs at 20 inches Hg vacuum, and bypass closure at 7 inches Hg vacuum.

High radiation levels in the main steamline tunnel above that due to the normal nitrogen and oxygen radioactivity are an indication of leaking fuel. A scram is initiated whenever such radiation level exceeds seven fifteen times normal background. The purpose of this scram is to reduce the source of such radiation to the extent necessary to prevent excessive turbine contamination. Discharge of excessive amounts of radioactivity to the site environs is prevented by the air ejector off-gas monitors which cause an isolation of the main condenser off-gas line provided the limit specified in Specification 3.8 is exceeded.

The main steamline isolation valve closure scram is set to scram when the isolation valves are 10% closed from full open. This scram anticipates the pressure and flux transient which would occur when the valves close. By scramming at this setting, the resultant transient is insignificant.

A reactor mode switch is provided which actuates or bypasses the various scram functions appropriate to the particular plant operating status (reference SAR Section 7.7.1.2). Whenever the reactor mode switch is in the Refuel or Startup/Hot Standby position, the turbine condenser low-vacuum scram and main steamline isolation valve closure scram are bypassed. This bypass has been provided for flexibility during startup and to allow repairs to be made to the turbine condenser. While this bypass is in effect, protection is provided against pressure or flux increases by the high-pressure scram and APRM 15% scram, respectively, which are effective in this mode.

If the reactor were brought to a hot standby condition for repairs to the turbine condenser, the main steamline isolation valves would be closed. No hypothesized single failure or single operator action in this mode of operation can result in an unreviewed radiological release.

The manual scram function is active in all modes, thus providing for a manual means of rapidly inserting control rods during all modes of reactor operation.

The IRM system provides protection against excessive power levels and short reactor periods in the startup and intermediate power ranges (reference SAR Sections 7.4.4.2 and 7.4.4.3). A source range monitor (SRM) system is also provided to supply additional neutron level information during startup but has no scram functions (reference SAR Section 7.4.3.2). Thus the IRM is required in the Refuel and Startup/Hot Standby modes in addition, protection is provided in this range by the APRM 15% scram as discussed in the bases for Specification 2.1. In the power range, the APRM system provides required protection (reference SAR Section 7.4.5.2.1). Thus, the IRM system is not required in the Run mode, the APRM's cover only the intermediate and power range; the IRM's provide adequate coverage in the startup and intermediate range.

The high-reactor pressure, high-drywell pressure, reactor low water level, and scram discharge volume high level scrams are required for the Startup/Hot Standby and Run modes of plant operation. They are therefore required to be operational for these modes of reactor operation.

The turbine condenser low-vacuum scram is required only during power operation and must be bypassed to start up the unit.

TABLE 3.1-1

REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENTS REFUEL MODE

Minimum Number of Operable or Tripped Instrument Channels per Trip System[1]	Trip Function	Trip Level Setting	Action[2]
1	Mode switch in shutdown		A
1	Manual scram		A
	IRM		
3	High flux	≤120/125 of full scale	A
3	Inoperative		
	APRM[3]		
2	High flux (15% scram)	Specification 2.1.A.2	A
2	Inoperative		A
2 (per bank)	High water level in scram discharge volume[4]	≤ 40 gallons per bank	A
2	High reactor pressure	≤1060 psig	A
2	High drywell pressure[5]	≤2 psig	A
2	Reactor low water level	≥8 inches[6]	A
2	Turbine condenser low vacuum[7]	≥ 21 inches Hg vacuum	A
2	Main steamline high radiation[12]	15 ≤50 X normal full power background	A
4	Main steamline isolation valve closure[7]	≤10% valve closure	A

TABLE 3.1-2

REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENTS STARTUP/HOT STANDBY MODE

Minimum Number of Operable or Tripped Instrument Channels per Trip System[1]	Trip Function	Trip Level Setting	Action[2]
1	Mode switch in shutdown		A
1	Manual scram		A
	IRM		
3	High flux	≤120/125 of full scale	A
3	Inoperative		A
	APRM[3]		
2	High flux (15% scram)	Specification 2.1.A.2	A
2	Inoperative		A
2	High-reactor pressure	≤1060 psig	A
2	High-drywell pressure[5]	≤2 psig	A
2	Reactor low water level	≥8 inches[8]	A
2 (per bank)	High water level in scram discharge volume[4]	≤ 40 gallons per bank	A
2	Turbine condenser low vacuum[7]	≥ 21 inches Hg vacuum	[illegible]
2	Main steamline high radiation[12]	≤15 X normal full power background	A
4	Main steamline isolation valve closure[7]	≤10% valve closure	A

TABLE 3.1.1

REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENTS RUN MODE

Minimum Number of Operable or Tripped Instrument Channels per Trip System(1)	Trip Function	Trip Level Setting	Action(2)
1	Mode switch in shutdown		A
1	Manual scram		A
	APRM(3)		
2	High flux (flow biased)	Specification 2.1.A.1	A or B
2	Inoperative		A or B
2	Downscale(11)	≥3/125 of full scale	A or B
2	High-reactor pressure	<1060 psig	A
2	High-drywell pressure	≤2 psig	A
2	Reactor low water level	≥8 inches (8)	A
2 (per bank)	High-water level in scram discharge volume	≤ 40 gallons per bank	A
2	Turbine condenser low vacuum	≥21 inches Hg vacuum	A or C
2	Main steamline high radiation(12)	≤~~50~~ 15 X normal full power background	A or C
4	Main steamline isolation valve closure(6)	≤10% valve closure	A or C
2	Turbine control valve fast closure(4)	≥40% turbine/generator load mismatch(10)	A or C
2	Turbine stop valve closure(4)	≤10% valve closure	A or C
2	Turbine EHC control fluid low pressure(4)	≥900 psig	A or C

Venturi tubes are provided in the main steamlines as a means of measuring steam flow and also limiting the loss of mass inventory from the vessel during a steamline break accident. In addition to monitoring steam flow, instrumentation is provided which causes a trip of Group 1 isolation valves. The primary function of the instrumentation is to detect a break in the main steamline, thus only Group 1 valves are closed. For the worst-case accident, main steamline break outside the drywell, this trip setting of 140% of rated steam flow, in conjunction with the flow limiters and main steamline valve closure, limits the mass inventory loss such that fuel is not uncovered, fuel temperatures remain less than 1500° F, and release of radioactivity to the environs is well below 10 CFR 100 guidelines (reference SAR Sections 14.2.3.9 and 14.2.3.10).

Temperature-monitoring instrumentation is provided in the main steamline tunnel to detect leaks in this area. Trips are provided on this instrumentation and when exceeded cause closure of Group 1 isolation valves. Its setting of 200° F is low enough to detect leaks of the order of 5 to 10 gpm; thus it is capable of covering the entire spectrum of breaks. For large breaks, it is a backup to high steam flow instrumentation discussed above, and for small breaks with the resulting small release of radioactivity, gives isolation before the guidelines of 10 CFR 100 are exceeded.

High-radiation monitors in the main steamline tunnel have been provided to detect gross fuel failure. This instrumentation causes closure of Group 1 valves, the only valves required to close for this accident. With the established setting of [illegible] times normal background and main steamline isolation valve closure, fission product release is limited so that 10 CFR 100 guidelines are not exceeded for this accident (reference SAR Section 12.2.1.7).

Pressure instrumentation is provided which trips when main steamline pressure drops below 825 psig. A trip of this instrumentation results in closure of Group 1 isolation valves. In the Refuel and Startup/Hot Standby modes this trip function is bypassed. This function is provided primarily to provide protection against a pressure regulator malfunction which would cause the control and/or bypass valve to open. With the trip set at 825 psig, inventory loss is limited so that fuel is not uncovered and peak cladding temperatures are much less than 1500° F, thus, there are no fission products available for release other than those in the reactor water (reference SAR Section 11.2.3).

The RCIC and the HPCI high flow and temperature instrumentation are provided to detect a break in their respective piping. Tripping of this instrumentation results in actuation of the RCIC or of HPCI isolation valves. Tripping logic for this function is the same as that for the main steamline isolation valves, thus all sensors are required to be operable or in a tripped condition to meet the single-failure criteria. The trip settings of 200° F and 300% of design flow and valve closure time are such that core uncovery is prevented and fission product release is within limits.

The instrumentation which initiates ECCS action is arranged in a one-out-of-two taken twice logic circuit. Unlike the reactor scram circuits, however, there is one trip system associated with each function rather than the two trip systems in the reactor protection system. The single-failure criteria are met by virtue of the fact that redundant core cooling functions are provided, e.g., sprays and automatic blowdown and high-pressure coolant injection. The specification requires that if a trip system becomes inoperable, the system which it activates is declared inoperable. For example, if the trip system for core spray A becomes inoperable, core spray A is declared inoperable and the out-of-service specifications of Specification 3.5 govern. This specification preserves the effectiveness of the system with respect to the single-failure criteria even during periods when maintenance or testing is being performed.

The control rod block functions are provided to prevent excessive control rod withdrawal so that MCPR does not go below the MCPR Fuel Cladding Integrity Safety Limit. The trip logic for this function is one out of n; e.g., any trip on one of the six APRM's, eight IRM's four SRM's will result in a rod block. The minimum instrument channel requirements assure sufficient instrumentation to assure that the single-failure criteria are met. The minimum instrument channel requirements for the RBM may be reduced by one for a short period of time to allow for maintenance, testing, or calibration. This time period is only ~3% of the operating time in a month and does not significantly increase the risk of preventing an inadvertent control rod withdrawal.

TABLE 3.2-1

INSTRUMENTATION THAT INITIATES PRIMARY CONTAINMENT ISOLATION FUNCTIONS

Minimum Number of Operable or Tripped Instrument Channels[1]	Instruments	Trip Level Setting	Action[2]
4	Reactor low water[5]	>144 inches above top of active fuel*	A
4	Reactor low low water	≥84 inches above top of active fuel*	A
4	High drywell pressure[5]	≤2 psig[3]	A
16	High flow main steamline[5]	≤140% of rated steam flow	B
16	High temperature main steamline tunnel	≤200° F	B
4	High radiation main steamline tunnel[6]	≤~~3~~ 15 x normal rated power background	B
4	Low main steam pressure[4]	≥825 psig	B
4	High flow RCIC steamline	≤300% of rated steam flow[7]	C
16	RCIC turbine area high temperature	≤200° F	C
4	High flow HPCI steamline	≤300% of rated steam flow[7]	D
16	HPCI area high temperature	≤200° F	D

Notes

1. Whenever primary containment integrity is required, there shall be two operable or tripped systems for each function, except for low pressure main steamline which only need be available in the Run position.
2. Action: If the first column cannot be met for one of the trip systems, that trip system shall be tripped.

   If the first column cannot be met for both trip systems, the appropriate actions listed below shall be taken.

   A. Initiate an orderly shutdown and have the reactor in Cold Shutdown condition in 24 hours.

   B. Initiate an orderly load reduction and have reactor in Hot Standby within 8 hours.

   C. Close isolation valves in RCIC system.

   D. Close isolation valves in HPCI subsystem.
3. Need not be operable when primary containment integrity is not required.
4. The isolation trip signal is bypassed when the mode switch is in Refuel or Startup/Hot Shutdown.
5. This instrumentation also isolates the control room ventilation system.
6. This signal also automatically closes the mechanical vacuum pump discharge line isolation valves.
7. Includes a time delay of 3≤t≤10 seconds.

* Top of active fuel is defined as 360" above vessel zero for all water levels used in the LOCA analysis (see Bases 3.2).

Loss of condensate vacuum occurs when the condenser can no longer handle heat input. Loss of condenser vacuum initiates a closure of the turbine stop valves and turbine bypass valves, which eliminates the heat input to the condenser. Closure of the turbine stop and bypass valves causes a pressure transient, neutron flux rise, and an increase in surface heat flux. To prevent the cladding safety limit from being exceeded if this occurs, a reactor scram occurs on turbine stop valve closure. The turbine stop valve closure scram function alone is adequate to prevent the cladding safety limit from being exceeded in the event of a turbine trip transient with bypass closure.

The condenser low-vacuum scram is a backup to the stop valve closure scram and causes a scram before the stop valves are closed, thus the resulting transient is less severe. Scram occurs at 21 inches Hg vacuum, stop valve closure occurs at 20 inches Hg vacuum, and bypass closure at 7 inches Hg vacuum.

High radiation levels in the main steamline tunnel above that due to the normal nitrogen and oxygen radioactivity are an indication of leaking fuel. A scram is initiated whenever such radiation level exceeds fifteen seven times normal background. The purpose of this scram is to reduce the source of such radiation to the extent necessary to prevent excessive turbine contamination. Discharge of excessive amounts of radioactivity to the site environs is prevented by the air ejector off-gas monitors, which cause an isolation of the main condenser off-gas line provided the limit specified in Specification 3.8 is exceeded.

The main steamline isolation valve closure scram is set to scram when the isolation valves are 10% closed from full open. This scram anticipates the pressure and flux transient which would occur when the valves close. By scramming at this setting, the resultant transient is insignificant.

A reactor mode switch is provided which actuates or bypasses the various scram functions appropriate to the particular plant operating status (reference SAR Section 7.7.1.2). Whenever the reactor mode switch is in the Refuel or Startup/Hot Standby position, the turbine condenser low-vacuum scram and main steamline isolation valve closure scram are bypassed. This bypass has been provided for flexibility during startup and to allow repairs to be made to the turbine condenser. While this bypass is in effect, protection is provided against pressure or flux increases by the high-pressure scram and APRM 15% scram, respectively, which are effective in this mode.

If the reactor were brought to a hot standby condition for repairs to the turbine condenser, the main steamline isolation valves would be closed. No hypothesized single failure or single operator action in this mode of operation can result in an unreviewed radiological release.

The manual scram function is active in all modes, thus providing for a manual means of rapidly inserting control rods during all modes of reactor operation.

The IRM system provides protection against excessive power levels and short reactor periods in the startup and intermediate power ranges (reference SAR Section 7.4.4.2 and 7.4.4.3). A source range monitor (SRM) system is also provided to supply additional neutron level information during startup but has no scram functions (reference SAR Section 7.4.3.2). Thus the IRM is required in the Refuel and Startup/Hot Standby modes. In addition, protection is provided in this range by the APRM 15% scram as discussed in the bases for Specification 2.1. In the power range the APRM system provides required protection (reference SAR Section 7.4.5.2). Thus, the IRM system is not required in the Run mode, the APRM's cover only the intermediate and power range, the IRM's provide adequate coverage in the startup and intermediate range.

The high-reactor pressure, high-drywell pressure, reactor low water level, and scram discharge volume high level scrams are required for the Startup/Hot Standby and Run modes of plant operation. They are therefore required to be operational for these modes of reactor operation.

The turbine condenser low vacuum scram is required only during power operation and must be bypassed to start up the unit.

TABLE 3.1-1

REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENTS REFUEL MODE

Minimum Number of Operable or Tripped Instrument Channels per Trip System(1)	Trip Function	Trip Level Setting	Action(2)
1	Mode Switch in shutdown		A
1	Manual scram		A
	IRM		
3	High flux	≤ 120/125 of full scale	A
3	Inoperative		
	APRM(3)		
2	High flux (15% scram)	Specification 2.1.A.2	A
2	Inoperative		A
2 (per bank)	High water level in scram discharge volume(4)	≤ 40 gallons per bank	A
2	High-reactor pressure	≤ 1060 psig	A
2	High-drywell pressure(5)	≤ 2 psig	A
2	Reactor low water level	≥ 8 inches(8)	A
2	Turbine condenser low vacuum(7)	≥ 21 inches Hg vacuum	A
2	Main steamline high radiation(12)	≤ 15 ⑦ X normal full power background	A
4	Main steamline isolation valve closure(7)	≤ 10% valve closure	A

TABLE 3.1-2

REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENTS STARTUP/HOT STANDBY MODE

Minimum Number of Operable or Tripped Instrument Channels per Trip System[(1)]	Trip Function	Trip Level Setting	Action[(2)]
1	Mode Switch in shutdown		A
1	Manual scram		A
	IRM		
3	High flux	≤ 120/125 of full scale	A
3	Inoperative		A
	APRM[(3)]		
2	High flux (15% scram)	Specification 2.1.A.2	A
2	Inoperative		A
2	High-reactor pressure	≤ 1060 psig	A
2	High-drywell pressure[(5)]	≤ 2 psig	A
2	Reactor low water level	≥ 8 inches[(8)]	A
2 (per bank)	High water level in scram discharge volume[(4)]	≤ 40 gallons per bank	A
2	Turbine condenser low vacuum[(7)]	≥ 21 inches Hg vacuum	A
2	Main steamline high radiation[(12)]	≤ 15 ⑦ X normal full power background	A
4	Main steamline isolation valve closure[(7)]	≤ 10% valve closure	A

TABLE 3.1-3

REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENTS RUN MODE

Minimum Number of Operable or Tripped Instrument Channels per Trip System[(1)]	Trip Function	Trip Level Setting	Action[(2)]
1	Mode Switch in shutdown		A
1	Manual scram		A
	APRM[(3)]		
2	High flux (flow biased)	Specification 2.1.A.1	A or B
2	Inoperative		A or B
2	Downscale[(11)]	≥ 3/125 of full scale	A or B
2	High-reactor pressure	≤ 1060 psig	A
2	High-drywell pressure	≤ 2 psig	A
2	Reactor low water level	≥ 8 inches[(8)]	A
2 (per bank)	High-water level in scram discharge volume	≤ 40 gallons per bank	A
2	Turbine condenser low vacuum	≥ 21 inches Hg vacuum	A or C
2	Main steamline high radition[(12)]	≤ 15 X normal full power background	A or C
4	Main steamline isolation valve closure[(6)]	≤ 10% valve closure	A or C
2	Turbine control valve fast closure[(9)]	≥ 40% turbine/generator load mismatch [(10)]	A or C
2	Turbine stop valve closure[(9)]	≤ 10% valve closure	A or C
2	Turbine EHC control fluid low pressure[(9)]	≥ 900 psig	A or C

Venturi tubes are provided in the main steamlines as a means of measuring steam flow and also limiting the loss of mass inventory from the vessel during a steamline break accident. In addition to monitoring steam flow, instrumentation is provided which causes a trip of Group 1 isolation valves. The primary function of the instrumentation is to detect a break in the main steamline, thus only Group 1 valves are closed. For the worst-case accident, main steamline break outside the drywell, this trip setting of 140% of rated steam flow, in conjunction with the flow limiters and main steamline valve closure, limits the mass inventory loss such that fuel is not uncovered, fuel temperatures remain less than 1500° F, and release of radioactivity to the environs is well below 10 CFR 100 guidelines (reference SAR Sections 14.2.3.9 and 14.2.3.10).

Temperature-monitoring instrumentation is provided in the main steamline tunnel to detect leaks in this area. Trips are provided on this instrumentation and when exceeded cause closure of Group 1 isolation valves. Its setting of 200° F is low enough to detect leaks of the order of 5 to 10 gpm; thus it is capable of covering the entire spectrum of breaks. For large breaks, it is a backup to high-steam flow instrumentation discussed above, and for small breaks with the resulting small release of radioactivity, gives isolation before the guidelines of 10 CFR 100 are exceeded.

High-radiation monitors in the main steamline tunnel have been provided to detect gross fuel failure. This instrumentation causes closure of Group 1 valves, the only valves required to close for this accident. With the established setting of Q times normal background and main steamline isolation valve closure, fission product release is limited so that 10 CFR 100 guidelines are not exceeded for this accident (reference SAR Section 12.2.1.7).

Pressure instrumentation is provided which trips when main steamline pressure drops below 825 psig. A trip of this instrumentation results in closure of Group 1 isolation valves. In the Refuel and Startup/Hot Standby modes this trip function is bypassed. This function is provided primarily to provide protection against a pressure regulator malfunction which would cause the control and/or bypass valve to open. With the trip set at 825 psig, inventory loss is limited so that fuel is not uncovered and peak cladding temperatures are much less than 1500° F; thus, there are no fission products available for release other than those in the reactor water (reference SAR Section 11.2.3).

The RCIC and the HPCI high flow and temperature instrumentation are provided to detect a break in their respective piping. Tripping of this instrumentation results in actuation of the RCIC or of HPCI isolation valves. Tripping logic for this function is the same as that for the main steamline isolation valves, thus all sensors are required to be operable or in a tripped condition to meet the single-failure criteria. The trip settings of 200° F and 300% of design flow and valve closure time are such that core uncovery is prevented and fission product release is within limits.

The instrumentation which initiates ECCS action is arranged in a one-out-of-two taken twice logic circuit. Unlike the reactor scram circuits, however, there is one trip system associated with each function rather than the two trip systems in the reactor protection system. The single-failure criteria are met by virtue of the fact that redundant core cooling functions are provided, e.g., sprays and automatic blowdown and high-pressure coolant injection. The specification requires that if a trip system becomes inoperable, the system which it activates is declared inoperable. For example, if the trip system for core spray A becomes inoperable, core spray A is declared inoperable and the out-of-service specifications of Specification 3.5 govern. This specification preserves the effectiveness of the system with respect to the single-failure criteria even during periods when maintenance or testing is being performed.

The control rod block functions are provided to prevent excessive control rod withdrawal so that MCPR does not go below the MCPR Fuel Cladding Integrity Safety Limit. The trip logic for this function is one out of n; e.g., any trip on one of the six APRM's, eight IRM's, or four SRM's will result in a rod block. The minimum instrument channel requirements assure sufficient instrumentation to assure that the single-failure criteria are met. The minimum instrument channel requirements for the RBM may be reduced by one for a short period of time to allow for maintenance, testing, or calibration. This time period is only ~3% of the operating time in a month and does not significantly increase the risk of preventing an inadvertent control rod withdrawal.

TABLE 3.2-1

INSTRUMENTATION THAT INITIATES PRIMARY CONTAINMENT ISOLATION FUNCTIONS

Minimum Number of Operable or Tripped Instrument Channels[1]	Instruments	Trip Level Setting	Action[2]
4	Reactor low water[3]	>144 inches above top of active fuel*	A
4	Reactor low low water	≥84 inches above top of active fuel*	A
4	High drywell pressure[3]	≤2 psig[3]	A
16	High flow main steamline[3]	≤140% of rated steam flow	B
16	High temperature main steamline tunnel	≤200 °F	B
4	High radiation main steamline tunnel[5]	≤15 x normal rated power background	B
4	Low main steam pressure[4]	≥825 psig	B
4	High flow RCIC steamline	≤300% of rated steam flow[7]	C
16	RCIC turbine area high temperature	≤200 °F	C
4	High flow HPCI steamline	≤300% of rated steam flow[7]	D
16	HPCI area high temperature	≤200 °F	D

Notes

1. Whenever primary containment integrity is required, there shall be two operable or tripped systems for each function, except for low pressure main steamline which only need be available in the Run position.
2. Action: If the first column cannot be met for one of the trip systems, that trip system shall be tripped.

   If the first column cannot be met for both trip systems, the appropriate actions listed below shall be taken:

   A. Initiate an orderly shutdown and have the reactor in Cold Shutdown condition in 24 hours.

   B. Initiate an orderly load reduction and have reactor in Hot Standby within 8 hours.

   C. Close isolation valves in RCIC system.

   D. Close isolation valves in HPCI subsystem.
3. Need not be operable when primary containment integrity is not required.
4. The isolation trip signal is bypassed when the mode switch is in Refuel or Startup/Hot Shutdown.
5. This instrumentation also isolates the control room ventilation system.
6. This signal also automatically closes the mechanical vacuum pump discharge line isolation valves.
7. Includes a time delay of 3≤t≤10 seconds.

* Top of active fuel is defined as 360" above vessel zero for all water levels used in the LOCA analysis (see Bases 3.2).

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