SAFETY EVALUATION REPORT

GUIDELINES FOR PERMANENT BWR HYDROGEN WATER CHEMISTRY INSTALLATIONS

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1 INTRODUCTION

1.1 Scope

The BWR Owner's Groups initially submitted the draft "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations" to the Director, NRC Office of Nuclear Reactor Regulation (NRR) on October 12, 1985. This staff's initial review indicated that the storage and use of large quantities of liquid hydrogen on a plant site raises the concern of potentially new and different accidents from those previously considered and evaluated as part of the facility licensing process.

In a letter to G. H. Neils, Chairman, Regulatory Advisory Committee, BWR Owner's Group II for IGSCC Research, (Bernaro, February 7, 1986), the staff indicated that licensees must consider whether proposed modifications in storage and use of relatively large quantities of liquid hydrogen and/or oxygen would result in hazards involving any of the three criteria for "an unreviewed safety question" defined in 10 CFR 50.59(a)(2). In a response (Neils, June 12, 1986) the Owner's Group requested a formal NRC staff review of all hydrogen and oxygen storage options (i.e., liquid hydrogen, liquid oxygen, and gaseous hydrogen).

A revised version of the "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations" was submitted to NRC for review (Neils, January 27, 1986), and the staff requested additional information concerning review of this submittal (Hulman, May 8, 1986). Another revision of the Guidelines (hereafter referred to as the Guidelines) incorporating responses to the staff's request for additional information was submitted (Neils, December 5, 1986) and is the basis for the review.

The electrolytic option that generates hydrogen and oxygen at the rate used in the process is not considered a storage option. Therefore, this report addresses liquid and gaseous hydrogen and liquid oxygen storage options and the electrolytic option.

1.2 Background

1.2.1 Hydrogen Water Chemistry

For IGSCC to occur in austenitic stainless steel, three conditions must exist simultaneously: a high stress region, a sensitized microstructure, and an adverse environment. In a boiling water reactor (BWR), the environment can mitigate the potential for IGSCC if the oxygen dissolved in the reactor coolant and its ionic impurity content are controlled.

BWR reactor coolant is demineralized water, typically containing 100 to 200 parts per billion (ppb) dissolved oxygen from the radiolytic decomposition of water. The electrochemical potential for BWR reactor coolant is near zero on the standard hydrogen electrode (SHE) scale. Even at a low conductivity (low ionic impurity), sensitized austenitic stainless steels are susceptible to IGSCC in 550°F (operating temperature) water at corrosion potentials near zero SHE. To mitigate the potential for IGSCC, the dissolved oxygen in the recirculating water can be reduced to less than 20 ppb by the addition of hydrogen to the feedwater. Dissolved hydrogen in the reactor coolant suppresses in-core radiolytic oxygen formation. BWR hydrogen water chemistry requiring control of oxygen to less than 20 ppb and a conductivity of less than 0.3 μS/cm will reduce the electrochemical potential to about -250 mV (SHE) resulting in a minimization of IGSCC. The (EPRI) BWR Owner's Group developed "BWR Water Chemistry Guidelines" (EPRI NP-3589-SR-LD), which must be met to obtain the full benefits of hydrogen water chemistry. These water chemistry guidelines also should be used as a basis for developing a plant-specific water chemistry control program. Hydrogen water chemistry appears to provide a means of suppressing both the initiation of IGSCC and the growth of preexisting cracks in sensitized stainless steel components in BWRs during power operation.

The Guidelines provide guidance for design, construction, and operation of permanent hydrogen addition systems at BWRs. Hydrogen water chemistry also requires an oxygen addition system that injects oxygen into the off-gas system to ensure that all excess hydrogen in the off-gas stream is recombined. Oxygen also may be needed for injection into the condensate and feedwater system to regulate reactor feedwater-dissolved oxygen between 20 to 50 ppb during power operation to minimize corrosion of the carbon steel in the condensate and feedwater system components. The Guidelines also document pertinent information on cryogenic oxygen storage and injection systems.

1.2.2 Hydrogen Explosion and Fire Experiences

Technical references in the Guidelines list approximately 100 incidents between 1921 and 1977 that produced flammable/explosive gas cloud releases. The potential dangers of explosive clouds are listed in the General Accounting Office report "Liquified Energy Gases Study," dated July 31, 1978.

National Aeronautic Space Administration has published a report (NASA TMX-71565, August 1974) describing incidents that occurred when liquified hydrogen was used as rocket engine fuel. Hydrogen deflagrations and explosions have occurred at reactor sites when gas storage tanks were being filled. An internal hydrogen tanks detonation also occurred at Los Alamos when a stream of oxygen accidentally leaked from a high pressure source into the hydrogen storage cylinder (Investigation Report, June 3, 1981).

Experimental liquid hydrogen spill tests indicate that the cryogenic liquid release to the ground will create a dense heavier-than-air plume that can travel up to 1500 feet before absorbing heat and gaining buoyancy (Authur D. Little, Inc., March 22, 1960). This cloud has regions of both explosive and flammable concentrations. National Bureau of Standards Monograph 168 indicates hydrogen is flammable in air in the range of 4.0-75.0 vol % and detonable in air in the range of 18.3 - 59.0 vol %. One gallon of liquid hydrogen has the explosive energy equivalence of 1.37 lbs of TNT (1 lb hydrogen is equivalent to 2.4 lbs TNT) in an open air explosion. One thousand scf of gaseous hydrogen is equivalent to 27.1 lbs of TNT.

1.2.3 Regulatory Concerns

During the past two decades the Atomic Energy Commission (AEC) and NRC have evaluated man-made hazards in the vicinity of nuclear power plants. These potential hazards have included the transport and nearby storage of munitions, explosives, toxic gases, and explosive/flammable gases. When such hazards have a sufficiently high probability of occurring, the plant's structures, systems, and components important to safety must be designed to withstand the possible effects of explosions or toxic gases without damage that would prevent a safe and orderly shutdown of the plant. Guidelines for the evaluation of these potential hazards are identified in the NRC's Standard Review Plan (SRP) (NUREG-0800) (Sections 2.2.1 and 2.2.2, "Identification of Potential Hazards In Site Vicinity," and 2.2.3, "Evaluation of Potential Accidents"). Regulatory Guide (RG) 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," Revision 1, describes vapor cloud explosions.

The Guidelines must address the potential impact of inadvertent releases or failures in hydrogen and oxygen storage and/ or injection systems on plant safety systems. The siting of hydrogen and oxygen storage facilities must be prescribed so that explosions and fires will not affect safety-related structures.

A second regulatory concern is the increased N-16 activity in the steam due to hydrogen injection. In normal BWR water chemistry, N-16 combines with oxygen to form water-soluble, nonvolatile nitrates and nitrites. However, when hydrogen is injected into the feedwater, N-16 forms a more volatile species (NH_3). Therefore, the steam phase N-16 levels are increased. Appropriate changes to the radiation protection program may be needed to compensate for increased radiation levels and to maintain exposures as low as is reasonably achievable (ALARA).

1.3 General System Description

The hydrogen water chemistry system is composed of a hydrogen supply, an oxygen supply, and hydrogen and oxygen injection systems. Hydrogen is supplied as a high pressure gas or as a cryogenic liquid. Oxygen is supplied as a cryogenic liquid. Hydrogen and oxygen can also be generated on site by the dissociation of water by electrolysis. (The electrolytic method is not a storage option and is, therefore, not reviewed in this report). Cryogenic hydrogen and oxygen are stored in vacuum-jacketed vessels. The liquified gases are vaporized by the use of ambient air vaporizers before the gases are pumped to the injection system. The gaseous hydrogen storage bank consists of American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) gas storage vessels. The hydrogen and oxygen systems include flow control and flow measuring equipment and necessary instrumentation and controls to ensure safe, reliable operation. Hydrogen gas is injected into the suction of the feedwater or condensate booster pumps to provide adequate mixing and dissolution.

Gaseous oxygen is injected into the portion of the off-gas system that is already diluted so that the addition of oxygen does not create a combustible mixture. The injected oxygen ensures that all excess hydrogen in the off-gas stream is recombined.

1.4 Design Criteria

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 1E, or environmentally qualified. However, proximity to safety-related equipment or other plant systems requires special consideration in the design, fabrication, installation, operation, and maintenance of hydrogen and oxygen addition systems. Hydrogen gas and cryogenic hydrogen and oxygen storage tanks are designed, fabricated, tested, and stamped in accordance with Section VIII, Division 1, of the ASME Code for unfired pressure vessels.

1.5 Hydrogen Storage Facilities

Gaseous hydrogen is stored in seamless ASME Code vessels at pressures up to 2400 psig and ambient temperature. Transportable vessels, which can also be used for gaseous hydrogen storage at 2650 psig and ambient temperature, are designed to Department of Transportation standards. The Guidelines cover tank sizes from 1000 to 14,000 scf. With either type of storage, the gas is routed through a pressure control station that maintains a constant hydrogen supply pressure to the hydrogen injection system. The tube bank should be supported to prevent movement in the event of line failure, and each tube should 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. The pressure control station should be of a manifold design with two full-flow parallel pressure-reducing regulators. An excess-flow check valve should be installed in the manifold immediately downstream of the regulators to limit the flow rate in the event of a line break. A tube trailer grounding assembly should be provided at each discharge stanchion to ground the tube trailer before hydrogen is transferred.

Liquid hydrogen is stored in a vacuum-jacketed vessel with a capacity of up to 20,000 gallons at pressures up to 150 psig and temperatures up to -403°F (saturated). In addition to ASME Code inspection requirements, inner vessel longitudinal welds should be examined radiographically. For overpressure protection, dual full-flow safety valves and emergency backup rupture discs are provided. Hydrogen tanks and delivery vehicles should be grounded, and the storage system should be protected from the effects of lightning. Excess flow protection should be added wherever a line break would release a quantity of hydrogen large enough to threaten safety-related structures. The liquid hydrogen will be vaporized by the use of ambient air vaporizers.

1.6 Oxygen Storage Facilities

Liquid oxygen is stored in a vacuum-jacketed vessel at pressures up to 250 psig and temperatures up to -251°F (saturated) with capacities between 3,000 and 11,000 gallons. Oxygen removed from storage vessels should be vaporized through ambient air vaporizers and routed through a pressure control station that maintains gas pressures within the desired range of the injection system. Overpressure protection of the storage tank is provided by dual full-flow safety valves and emergency backup rupture discs.

1.7 Gas Injection Systems

Excess flow valves should be installed at appropriate locations in the hydrogen line to restrict flow out of a broken line. To meet this requirement other options are that hydrogen lines in safety-related areas should either be designed to seismic Class I requirements or sleeved so that the outer pipe is directly vented to the outside (Branch Technical Position CMEB 9.5-1, Revision 2, July 1981, SRP 9.5.1). Feedwater hydrogen injection lines should contain a check valve to prevent feedwater from entering the hydrogen line and to protect upstream hydrogen gas components. Automatic isolation valves should be installed in each injection line to prevent hydrogen injection into a non-operating feedwater pump. Purge connections should be provided to completely purge air from the system before hydrogen is released into the line. Area hydrogen monitors should be located at high points where hydrogen may collect and above components where potential hydrogen leaks may occur. Hydrogen monitors should be located so that they can detect hydrogen with or without normal ventilation. System design should conform with pertinent sections of 10 CFR 50.48.

1.8 Instrumentation and Control

The instrumentation should (a) provide indication and/or recording of parameters necessary to monitor and control the hydrogen injection system and (b) indicate and/or alarm abnormal or undesirable conditions. Parallel flow control valves should be provided in the hydrogen injection line for system reliability and maintainability. The recommended trips of the hydrogen and oxygen injection system include: reactor scram, low residual oxygen in the off-gas, high area hydrogen concentration, low oxygen injection system supply pressure or flow, off-gas train or recombiner train trip, and high hydrogen flow.

Provisions should be made to continuously monitor the dissolved oxygen in the reactor coolant. The off-gas flow downstream of the recombiners should be continuously monitored for hydrogen and oxygen.

2 EVALUATION

2.1 Site Characteristics for Gaseous and Liquid Hydrogen Storage

The Guidelines reference the National Fire Protection Association (NFPA) standards 50A and 50B for the location of gaseous and/or liquid hydrogen supply systems, respectively. These include

- Ready access to delivery equipment and to authorized personnel; suitable roadways or other means of access for emergency equipment, such as fire department apparatus, shall be provided.

- Storage containers shall not be located under electric power lines or where they would be exposed should the lines fail.

- Storage containers shall not be located close to piping containing flammable or combustible liquids, flammable gases, or piping containing oxidizing material.

- Where it is necessary to locate the hydrogen containers on ground that is level with or lower than adjacent flammable and combustible liquid storage or oxygen storage, suitable protective means shall be taken (such as diking, diversion curbs, or grading) to prevent accumulation of liquids within 50 feet of the storage container. Liquified hydrogen storage containers should be located on ground higher than flammable and combustible liquid storage or liquid oxygen storage.

Other considerations for siting include

- The route used for hydrogen delivery on site should be appropriate.

- The storage facility shall be completely fenced, even when located in a security area, and it should be lighted to facilitate night surveillance.

- Truck barriers shall be installed around the perimeter of the storage facility for protection in case of vehicular accidents.

- The hydrogen storage facility shall be located so there is adequate separation between it and safety-related structures so that explosion and fire overpressures and thermal fluxes are within design considerations.

- Air pathways into safety-related structures should exceed a minimum separation distance so that the release from a possible pipe break is below the lower flammability limit of 4% before reaching the air pathway into safety-related structures.

2.2 Site characteristics for Liquid Oxygen Storage

The Guidelines reference NFPA 50 standards for the location of liquid oxygen storage systems. These include

- There shall be ready access to mobile supply equipment, at ground level, to authorized personnel.

- The location selected shall not be beneath electric power lines, piping containing all classes of flammable or combustible liquids, or piping containing flammable gases, nor should it be an area that would be impacted by the failure of these components.

- Noncombustible material surfacing shall be provided in an area extending at least 3 feet from points at ground level on which liquid oxygen might fall during operation of the system and filling of the storage container.

- When a liquid oxygen storage facility is on ground lower than all classes of adjacent flammable and liquid storage, suitable means shall be provided (such as by diking, diversion curbs, or grading) to prevent accumulation of flammable or combustible liquids under the oxygen storage facility.

Other considerations for siting include

- The route used for liquid oxygen delivery on the site should be appropriate.

- The storage facility shall be completely fenced, even when located within the security area, and it shall have lighting to facilitate night surveillance.

- Truck barriers shall be installed around the perimeter of the storage facility for protection in case of vehicular accidents.

- Liquid oxygen storage facility shall be located so that ingestion of oxygen-enriched atmospheres (above 30 volume %) into safety-related air intakes is not possible in the event of an oxygen spill.

2.3 Meteorological Considerations

A massive failure of a large pressurized cryogenic hydrogen storage tank would result in a turbulent release of the gas that may result in a fire or explosion.

To reduce the potential for impact on plant safety structures, the storage facility should be far enough from the safety structures so any overpressure it experiences from an explosion would not exceed that from hurricane or tornado winds.

Unconfined hydrogen-air mixtures generally burn rapidly, but without detonation, when they are initiated by heat, spark, or flame unless there is flame acceleration as a result of obstacles. In this case a deflagration/detonation transition may occur. Because hydrogen diffuses rapidly in air, it will not form persistent flammable mixtures when the gaseous hydrogen is released in open, unconfined areas. However, in confined areas, or when ignition of the hydrogen-air mixture is caused by a shock source equivalent to a blasting cap or small explosive charge, the mixture can detonate. Liquid hydrogen releases can produce dense plumes with flammable/detonable concentrations that can travel hundreds of feet before being diluted to a non-hazardous mixture.

An additional consideration is of the prevailing wind flow. A hydrogen leak in the presence of winds can lower the probability of a flammable or explosive environment near or at plant air intakes. The meteorological measurement program required at nuclear plants should serve as the source of this wind direction information.

Slow leaks of hydrogen gas outdoors or in unconfined areas tend to mix with the ambient air and not result in flammable or explosive mixtures.

The meteorological and siting considerations presented in the Guidelines are acceptable as a basis for establishing onsite hydrogen storage. Before individual plant facilities are installed the prevailing winds and structure locations should be reviewed.

2.4 Gaseous Hydrogen Safety Considerations

The Guidelines are based on the safety analysis of the failure of single vessels and do not address simultaneous failure of multiple storage vessels. In the case of the Los Alamos tube trailer, hydrogen explosion of a single tube did not damage the adjacent hydrogen vessels. This event provides a technical basis for assuming only single vessel failure (Investigation Report, June 3, 1981). At two reactor sites hydrogen explosions and fireballs during filling operations occurred over the storage tanks but did not damage the adjacent cylinders (Reportable Event No. 07950, March 5, 1987, NUREG/CR-3551, May 1985).

When a gaseous storage vessel ruptures, the expansion of the high-pressure gas results in turbulent mixing with the surrounding air. For hydrogen, the bulk of the release will go through the detonation limits before the wind can produce an explosive concentration plume that could travel far from the vicinity of the storage tank area.

The hydrogen storage area should be at a sufficient distance from safety-related structures so that the thermal flux from the burning hydrogen gas fire-ball or the blast overpressure from hydrogen detonation will not cause failure of the safety-related structures.

The staff has performed independent calculations and evaluations that confirm the following figures in the Guidelines for gaseous hydrogen storage systems:

- Figure 4-1, thermal flux vs. distance from fireball center
- Figure 4-2, minimum required separation distances to safety-related structures versus vessel size
- Figure 4-3, minimum required separation distance (to air pathways into safety-related structures) versus ID of pipe for release from 2450 psig gaseous hydrogen

The Guidelines recommend, in Appendix B, a method to determine separation distances for hydrogen storage to prevent damage to nuclear power plant safety structures in the event of a hydrogen explosion. Appendix B is based on earlier work performed by Sandia National Laboratories for NRC (NUREG/CR-2462). These recommendations are applicable for reinforced concrete or masonry walls that are at least 8 inches thick. Other structures with light-guage metal paneling walls and metal tanks should be evaluated on a case-by-case basis.

The staff reviewed the separation distance for hydrogen storage facilities with 8-inch or greater reinforced concrete or reinforced masonry walls (upper curve in Figure 4-2 and 4-5 of the Guidelines). This curve is based on the British Explosives Storage and Transport Committees recommendations (New York Academy of Sciences Annals. Vol. 1, 152, 1968). On the basis of this review, the staff concludes that the recommendations are reasonable and valid. The staff finds there are ample data from well-documented explosion experiments, damage records from accidental explosions, and war-time experiences (bomb damage), all of which were considered in the formulation of the recommendations.

The Guidelines provide separation distance from hydrogen storage facilities for 18-inch or greater reinforced concrete walls (curves (a) and (b) in Figures 4-2 and 4-5 of the Guidelines). Curves (a) and (b) are applicable for the indicated static pressure capacities and tensile steel factors, and are acceptable by the staff. The method of analysis for constructing these curves is conventional and generally follows the guidelines of the American Society of Civil Engineers (ASCE) Manual No. 58 (1980) and American Concrete Institute (ACI) 349-80 (April 1981).

The staff has not formally reviewed nor accepted the ASCE Manual. Special provisions for impulsive (blast) and impactive (missile) effects for concrete structures were addressed in the ACI 349-80 (April 1981) which has been accepted by the staff with the exception of certain ductility ratios. Appendix A to SRP 3.5.3) provides guidance for design of both steel and reinforced concrete structural elements (e.g., missile barriers, columns, slabs) subject to impactive or impulsive loads, such as impects due to missiles or blasts. Ductility ratios for structural steel members are given in Appendix A to SRP 3.5.3. For reinforced concrete members, the requirement of ductility ratios is specified in RG 1.142, Revision 1. American Concrete Institute (ACI) 349-80 is to be used in conjunction with RG 1.142, Revision 1, for reinforced concrete structures, and American Institute of Steel Construction (AISC) Specification ("Manual of Steel Construction") is to be used in conjunction with Appendix A to SRP 3.5.3 for steel structures. Because curves (a) and (b) in Figures 4-2 and 4-5 in the Guidelines comply with RG 1.142, they are acceptable if the ductility ratio is limited to 3.

The staff concludes that curves (a) and (b) in the Guidelines can be used for determining the separation distance for reinforced concrete walls from gaseous and liquid hydrogen storage facilities. Walls with different static pressure capacities and/or tensile steel factors can use the methods in Appendix B to the Guidelines, pages 10 through 13.

2.5 Liquid Hydrogen Safety Considerations

The major hazard from the storage and use of large quantities of cryogenic liquid hydrogen on reactor sites is that of producing flammable/explosive clouds that can drift near or be taken into air ventilation systems of safety-related structures. Cryogenic hydrogen released to the environment will form a dense heavier-than-air plume that will drift along with wind currents and by gravity to lower elevations until it gains sufficient heat to produce buoyancy. Experimental data indicate plume travel of the order of 1000 feet from a liquid hydrogen flow rate of 2-18 Kg/sec.

The staff has performed independent calculations to check the values shown in the Guidelines. The staff used NASA data to check the thermal flux data (Figure 4-4 in the Guidelines). Standard meteorological data were used to check the hydrogen concentrations at the nearest safety-related air intakes (Figure 4-6 in the Guidelines). The staff used the Guidelines (Hoehne and Luck, 1970) to determine the lower flammable concentrations from various sizes of pipe breaks in gaseous hydrogen lines. In addition, the staff noted blast overpressure effects on both reinforced brick houses and reinforced concrete houses from nuclear weapons tests. The staff also observed that the 5 psi overpressure that destroyed an unreinforced brick house had no effect on a reinforced concrete house that had been designed to comply with California Code for earthquake-resistant construction (Glasstone, 1962). These data indicate that Figure 4-5 of the Guidelines is conservative when it is applied to safety-related structural walls.

Licensees may use the minimum separation distance curves in Figure 4-5 of the Guidelines in requests for approval of permanent hydrogen water chemistry installations.

2.6 Liquid Oxygen Safety Considerations

The major threat from the release of cryogenic liquid oxygen is the formation of dense plumes that disperse by slumping (due to gravity) and by motion of existing winds. The potential for oxygen clouds reaching flammable materials or entering safety-related air intakes should be avoided. Oxygen will not explode and is nonflammable, but ignition of combustible materials may occur more readily in an oxygen-rich atmosphere than in air.

The liquid oxygen tank capacity versus distance curves were checked by independent staff analysis and found to be acceptable (Figure 4-8 of the Guidelines). The recommended separation distances between liquid storage tanks and safety-related air intakes are reasonable. The separation distances are such that the vapor cloud released from a failed tank would disperse sufficiently so that the oxygen content at the air intakes will not support increased combustibility of ignitible materials.

2.7 Radiation Protection/ALARA Program

The staff has also reviewed the Guidelines to ensure that the dose rate increase in plant areas due to N-16 equilibrium changes during hydrogen addition has been considered in plant operation procedures. To reduce workers' doses, the Guidelines uses a programmatic approach that outlines additional health physics procedures and that is intended to augment current plant radiation protection procedures (current procedures would not change). Specifically, the Guidelines recommend an appropriate ALARA commitment for plant management, an initial and continuous radiation survey program, potential plant shielding changes, and potential maintenance activities. These programmatic procedures, in addition to normal plant radiation protection procedures, are sufficient to ensure that during hydrogen addition the plant will continue to meet the requirement of 10 CFR 20 and the recommendations of RG 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposure at Nuclear Power Stations Will Be as Low as is Reasonably Achievable." Thus the procedures are acceptable. These procedures will also ensure compliance with site boundary radiological limits required by 40 CFR 190.

2.8 Main Steam Line Radiation Monitoring

The staff reviewed the impact of the proposed changes on previously approved safety analyses of anticipated operational occurrences and postulated accidents.

The main steam line radiation monitors (MSLRMs) provide reactor scram and reactor vessel and primary containment isolation signals when high-activity levels are detected in the main steam lines. Additionally, these monitors serve to limit radioactivity release in the event of fuel failures. Technical Specification (TS) changes are needed to accommodate the expected increase in main steam activity levels (from increased N-16 levels in the steam phase) as a result of hydrogen injection into the primary system.

The BWR Owners Group state that the only transient or postulated accident that takes credit for the main steam line high radiation scram and isolation signals is the control rod drop accident (CRDA). The staff notes that for a CRDA, the primary function of the MSLRMs is to limit the transport of activity released from failed fuel to the turbine and condensers by initiating closure of the main steam isolation valves and thus isolating the reactor vessel. Main steam line high radiation will also produce a reactor scram signal and will isolate the mechanical vacuum pump and the gland seal steam exhaust system to reduce leakage of fission products to the atmosphere from the turbine and condensers. Reactor scram in the event of a CRDA, however, would be initiated by signals from the neutron monitoring system.

Generic analyses of the consequences of a CRDA have shown that fuel failures are not expected to result from a CRDA occurring at greater than 10% power (Stirn et al., March 1972; Strin et al., January 1973; Strin et al., July 1972). This is primarily a result of analyses that show that as power increases, the severity of the CRDA rapidly decreases as a result of the effects of increased void formation and increased Doppler reactivity feedback. The hydrogen injection will be restricted to power levels above 20% of rated power for all plants.

Main steam line radiation levels can increase up to approximately fivefold with hydrogen water chemistry. The majority of BWRs have a TS requirement for the MSLRM setpoint that is less than or equal to three 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 7 to ten 10 times normal full-power background, a setpoint change may not be required with hydrogen water chemistry.

For plants at which credit is taken for an MSLRM-initiated isolation in the CRDA, a dual setpoint approach may be used. At most plants, the MSLRM setpoint is specified in the plant TS as some factor times rated full-power radiation background. With hydrogen addition, the full-power background could increase up to five times that without hydrogen addition. Below 20% of rated power or the power level required by the FSAR or TS, the existing setpoint is maintained at the TS factor above normal full-power background, and hydrogen should not be injected. At about 20% of rated power, the MSLRM setpoint should be readjusted to the same TS factor above the rated full-power background with hydrogen addition. This adjustment will be made by the plant personnel during startup and shutdown. Plant power will remain constant during this adjustment process. Thus, the TS factor by which the MSLRM setpoint is adjusted remains the same with and without hydrogen addition, but the background radiation level increase with hydrogen addition. If an unanticipated power reduction event occurs so that the reactor power is below 20% without the required setpoint change, control rod motion should be suspended (except for scram or other emergency actions) until the necessary setpoint adjustment is made. TS changes will be required to suspend control rod motion during setpoint adjustment.

On the basis the discussion above, the staff finds that section 8 of the Guidelines is acceptable for referencing in license applications to the extent specified and under the limitations delineated in the report and this technical evaluation.

3 CONCLUSION

On the basis of the above evaluation, the staff finds that the Licensing Topical Report, "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations," 1987 revision, is acceptable for reference in future licensee requests for approval of permanent hydrogen water chemistry installations. The basis for this acceptance is that the Guidelines meet the applicable requirements and guidance from the following regulatory guides, standard review plan sections, branch technical positions, and federal regulations:

- Regulatory Guide 1.91, "Evaluation of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," Revision 1, February 1978

- Regulatory Guide 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," Revision 1, October 1981

- Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposure at Nuclear Power Stations Will Be as Low as is Reasonably Achievable," Revision 3, June 1978

- Standard Review Plant Section 9.5.1, Branch Technical Position CMEB 9.5-1 "Guidelines for Fire Protection for Nuclear Power Plants," July 1981
- Standard Review Plan Section 3.5.3, "Barrier Design Procedures," Revision 1, July 1981
- 10 CFR 50.48, "Fire Protection"
- 40 CFR 190, "Protection Environment, Environmental Radiation Protection Standards for Nuclear Power Operations"

A licensee request for approval for a permanent hydrogen water chemistry installation that incorporates this Licensing Topical Report by reference should include the following information:

- Any exceptions or deviations from the "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations," 1987 Revision, Licensing Topical Report
- Justification that any exceptions or deviations from the Guidelines will not affect the safety of the plant or the public
- The maximum quantity of stored gaseous hydrogen and/or liquid hydrogen and oxygen and its distance from safety-related structures
- Technical Specification changes, if required, to accommodate the expected increase in main steam line radiation setpoint
- A description of hydrogen and oxygen storage facilities, including safety features
- A description of hydrogen and oxygen injection subsystems, including instrumentation, controls, and safety features
- The delivery route of hydrogen and oxygen supply tank trucks on site, including truck tank capacity.
- A radiological protection program to ensure that radiological exposures to plant personnel and the general public are consistent with ALARA requirements
- A discussion on implementation of BWR Owner's Group Water Chemistry Guidelines

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