10.23 HYDROGEN WATER CHEMISTRY SYSTEM (HWC)

10.23.1 Power Generation Objective

The Hydrogen Water Chemistry (HWC) System injects hydrogen into the feedwater system at the suction of the condensate booster pumps to mitigate Intergranular Stress Corrosion Cracking (IGSCC) in the recirculation piping and the reactor internals. The injected hydrogen causes a reduction in the dissolved oxygen within the reactor internals and recirculation piping and lowers the radiolytic production of hydrogen and oxygen in the vessel core region.

10.23.2 Power Generation Design Basis

The purpose of the Hydrogen Water Chemistry (HWC) System at Browns Ferry Nuclear Plant (BFN) is to reduce rates of IGSCC in recirculation piping and lower reactor vessel internals. The corrosion potential in an operating BWR can be reduced by injecting hydrogen into the reactor feedwater system. In high gamma radiation regions, such as in the downcomer, excess hydrogen reacts with H_2O_2, oxygen and other oxidizing species to form water. Therefore, hydrogen injection will result in a less oxidizing environment and, thus, lower corrosion potentials. The target Electrochemical Corrosion Potential (ECP) is - 230 mV Standard Hydrogen Electrode (SHE). At this target potential, and normal BWR water quality, new cracks should not initiate for piping and vessel internals, and existing cracks will have extremely low and tolerable crack growth rates.

Noble Metal Chemical Application (NMCA) involves an occasional batch injection of a small amount of noble metal into the reactor coolant. The noble metal acts as a catalyst for hydrogen and oxygen recombination reactions and allows for a lower HWC feedwater hydrogen injection rate. The lower HWC feedwater hydrogen injection rate with NMCA lowers personnel operating doses and provides improved corrosion protection of reactor vessel internals (lower ECPs).

The storage system is designed to perform the following functions at all times. Failure modes associated with gas supply system will not impact ability of the station to safely shutdown. The cryogenic hydrogen storage tanks are qualified to withstand seismic loads and tornado winds but are assumed to fail in place from tornado missiles. The Cryogenic Oxygen tank may fail under either seismic or tornado wind loads. Gaseous hydrogen storage tubes are qualified to withstand either seismic loads, tornado wind loads, and tornado missiles.

The balance of the HWC System is designed to perform the following functions:

a. Inject sufficient hydrogen into the feedwater stream to be capable of maintaining up to a 2.7 ppm dissolved hydrogen concentration in order to minimize the potential for stress corrosion cracking of lower vessel internal components.

b. Inject sufficient oxygen into the offgas system to ensure that the excess hydrogen in the offgas stream is recombined.

10.23.3 Description

The HWC System injects hydrogen into the reactor feedwater stream at the suction of each condensate booster pump. Hydrogen addition to the feedwater results in an excess ratio of hydrogen to oxygen at the entrance to the Offgas System. Therefore, the HWC System also injects oxygen between the last stage steam jet air ejector and offgas preheater to maintain a stoichiometric mixture of hydrogen and oxygen in the recombiner. The net result is that the Offgas System operates at the same stoichiometric conditions as without HWC. The offgas monitor panel contains dual hydrogen and oxygen analyzers to monitor the recombiner exit conditions to alert plant personnel on abnormal oxygen or hydrogen concentrations and shutdown the HWC system.

Because oxygen is reduced in the steam, condensate oxygen also is reduced. At condensate oxygen concentration values less than approximately 15 ppb, carbon steel corrosion rates are accelerated due to stripping of the oxide layer. To counter this effect, a small amount of oxygen is injected into the condensate pump suction header.

The HWC System control logic, which is contained within the HWC Main Control Panel, provides processing of signal inputs, determination of alarm and shut down conditions, and output of data and shutdown signals. The panel supplies alarm status and display, process parameter displays, and operator interface capabilities. Output terminals are supplied that provide signals to the main control room for remote (plant control room) shutdown and alarm status. Process data is stored locally in the HWC Main Control Panel computer and can be output on a portable disk drive. Capability is provided to supply output of process parameter data to a remote data acquisition system or station computer. The controller is capable of automatically adjusting hydrogen and oxygen flows as a function of reactor power, which is based on feedwater flow, to maintain a constant hydrogen concentration in the feedwater.

Hydrogen and oxygen gases are supplied by an onsite Cryogenic Tank Farm Facility, which is owned, operated, and maintained by the gas supply contractor. The liquid is vaporized as needed and in the case of hydrogen, compressed to the required supply pressure. Oxygen is not compressed but supplied to the process at the liquid tank pressure. Hydrogen is supplied from a nominal 15,000 gallon cryogenic bulk liquid tank which is administratively restricted to less than 10,000 lb capacity and the oxygen is supplied from a nominal 11,000 gallon cryogenic bulk liquid tank. These tanks are designed and constructed in accordance with the ASSME Boiler & Pressure Vessel Code, Section VIII, Division 1. Hydrogen storage capacity is limited to less than 10,000 lbs which is below the threshold limit of an OSHA process safety plan and an EPA Risk Management Plan per OSHA 1910.119 and EPA 40 CFR 68.

Excess flow check valve protection is provided for all hydrogen and oxygen piping outside of the storage facilities to ensure that adequate separation is maintained between a large leakage source and any safety related structures or air pathways into safety related structures. The hydrogen water chemistry system trips on offgas system isolation and on low feedwater flow, which will occur soon after all scram trips. Isolation valves fail close on loss of electric or pneumatic power to prevent inadvertent injection of gases during any station transient.

The hydrogen water chemistry system includes six hydrogen gas concentration detectors, with two attached to the hydrogen flow control module, one mounted above each of the feedwater pumps (three total) and one above the hydrogen injection piping entrance to the turbine building. These detector units continuously monitor ambient air and upon detecting a high hydrogen gas concentration will isolate the hydrogen supply line which results in an HWC system trouble signal in the main control room.

Connections are provided to allow hydrogen piping to be completely purged of air before hydrogen is introduced into the line. Suitable valves are provided to cross connect the purge outlet to a hydrogen vent line, which contains a flame arrestor.

10.23.4 Safety Evaluation

The hydrogen water chemistry system, including the gas vendor equipment, is designed and installed in accordance with EPRI Report NP-5283-SR-A, “Guidelines for Permanent BWR Hydrogen Water Chemistry Installations - 1987 Revision.” This system serves no safety function. It is not required to effect or support the safe shutdown of the reactor or perform in the operation of reactor safety features. Systems analysis has shown that failure of this system will not compromise any safety-related systems or prevent safe shutdown. There is no equipment redundancy associated with the injection control functions for the hydrogen water chemistry system. Equipment redundancy is only provided at the tank farm facility to ensure a reliable hydrogen supply tot he hydrogen water chemistry and generator hydrogen cooling systems.

The hydrogen storage vessels are designed to maintain integrity during a design basis earthquake. The liquid hydrogen tank, including all integral tank attached piping, is designed and qualified to Uniform Building Code (UBC) seismic zone 4 requirements. The liquid hydrogen filled piping between the tank, hydrogen pumps, and vaporizers is qualified to UBC seismic zone 1 requirements. Both of these are conservative with respect to the BFN design basis earthquake acceleration values.

The design of foundations for the hydrogen storage tank includes tank seismic loading.

Foundations for permanent liquid hydrogen and oxygen storage tanks and gaseous hydrogen storage vessels in support of the station HWC System are designed to keep the associated vessel in place during a design basis tornado. Vessel failure with the corresponding loss of all contents is permitted during the tornado. Siting considerations for the storage facilities included evaluation of impact to nearby safety related structures due to fireball or explosion of hydrogen, and oxygen vapor cloud ingestion into safety related air pathways. Leakage from or failure of either facility was evaluated as acceptable with no adverse impact to safe station shutdown. Redundant pressure relief (hydrogen and oxygen) and vent stack design (hydrogen only) vessels provides protection of storage vessels and liquid filled piping from thermal overpressure due to external fire. Due to the explosion potential of hydrogen leaks, there is no fire abatement system. Hydrogen fires are to be allowed to burn until hydrogen source is isolated.

The location of the liquid hydrogen tank was selected to prevent loss of power lines to/from the switchyard or damage station transformers due to hydrogen facility catastrophic failure. Based on the minimum separation distance of over 2,300 feet the overpressure wave associated with tank farm facility failure is bounded by the design tornado wind loads for these structures/components.

10.23.5 Inspection and Testing

The functional operability of the HWC gas storage system and HWC injection equipment was initially tested at the time of system installation to confirm system operation and functional trips.

The gas tank farm facility is owned, maintained, and operated by the selected gas vendor. Therefore, this equipment is not considered permanent plant equipment.