CONDENSATE-FEEDWATER-BOILER SYSTEM
ON-LINE ANALYZERS

On-Line Analyzer	Sample Point	Alarm Points	Comments
pH	1. L.P. Heaters 2. H.P. Heaters 3. Boilers	**Feedwater** Low 9.3 High 9.5 **Boilers** Low 8.7 High 9.7	Feedwater pH controlled by Morpholine addition (added at condensate polisher discharge when polishers are in service). Optimum pH range for magnetite preservation and carbon steel corrosion. Boiler pH controlled by feedwater pH and by phosphate addition.
Cation Conductivity	1. Condensate Extraction Pump 2. H.P. Heater Outlet 3. Outlet of Polisher Vessels 4. Condenser Hotwells	**Cond/Feedwater** High 0.1 mS/m **Polishers** High 0.04 mS/m	Used to detect low concentrations of anions (e.g., chloride, sulfate). Salts converted to acids. Chemicals added for corrosion control removed (morpholine, hydrazine). **Condensers** tube leaks **Polishers** exhausted resin (anions coming off the resin). **Feedwater** low concentrations of anions in the feedwater
Specific Conductivity	1. Outlet of Polisher Vessels 2. Boiler B/D Composite	Conductivity will depend upon chemical feed concentration in the cond/feedwater (morpholine & hydrazine). Boiler B/D conductivity will depend upon phosphate dosage in the boilers and also the cond/feedwater morpholine & hydrazine concentrations.	Specific Conductivity is a measure of the total ionic concentration in the water. Used to give an indication of the concentration of treatment chemical concentration in the condensate/feedwater and steam generators (morpholine, hydrazine and phosphate).
Dissolved Oxygen	1. L.P. Heater Outlet 2. H.P. Heater Outlet	**L.P. Heater Outlet** High 0.050 mg/Kg **H.P. Heater Outlet** High 0.010 mg/Kg	Most corrosive impurity in the condensate-feedwater-boiler system. Controlled by condenser air extraction, hydrazine addition and the D/A.

CONDENSATE-FEEDWATER-BOILER SYSTEM
ON-LINE ANALYZERS

On-Line Analyzer	Sample Point	Alarm Points	Comments
Hydrazine	1. L.P. Heater Outlet 2. Heater Outlet	**L.P. Heater Outlet** Low 0.060 mg/Kg High 0.080 mg/Kg **H.P. Heater Outlet** Low 0.060 mg/Kg High 0.080 mg/Kg	Residual maintained in order to ensure complete dissolved oxygen removal. Too high a hydrazine concentration can result in increased corrosion of the carbon steel piping (loss of magnetite layer).
Sodium	1. Condenser Hotwells 2. Polisher Service Vessels 3. Main CEP discharge	**Condenser Hotwells** High 0.005 mg/Kg **Main CEP Discharge** High 0.005 mg/Kg **Pol Service Vessels** High 0.002 mg/Kg	Indication of condenser tube leaks Sodium coming off the polisher service vessels would indicate cation resin exhaustion.
Gross Gamma	1. Boiler B/D Composite	**B/D Composite** High 250 cps	Indication of boiler tube leaks. PHT water entering the boiler water. Gives an indication of gross gamma activity in the boiler water.
Tritium	1. Boiler Steams	**Boiler Steams** High 1.85E6 Bq/Kg	Indication of boiler tube leaks. PHT water entering the boiler water.
D_2O	1. Boiler Steams	**Boiler Steams** High 160 mg/Kg	Indication of boiler tube leaks. PHT water entering the boiler water. Not as fast an indication as boiler steam tritium's for detection of boiler tube leaks.

NUCLEAR SYSTEMS

System	Main Parameters Monitored	Chemistry Specifications		Comments	
Main Moderator System	**pH**	**pH**	**4.5 -7.0**	**pH**	Maintained neutral to slightly acidic for reactivity concerns (gadolinium precipitation occurs at pH values of 7.0 and higher).
	Specific Conductivity	**Specific Conductivity**	**< 0.10 mS/m**	**Specific Conductivity**	Maintained as low as possible. Indication of the presence of impurities (or the presence of gadolinium). Increased conductivity will result in increased D_2 & O_2 production in the water which will then find its way into the cover gas.
	Dissolved D_2	**Dissolved D_2**	**< 13.0 ml/Kg**	**Dissolved D_2**	Monitored to prevent high concentrations of D_2 from entering the cover gas. Increased D_2 in the water indicates the presence of impurities in the system. The dissolved D_2 will increase when
	Chloride	**Chloride**	**< 0.20 mg/Kg**	pulling	Gd following a poison outage.
	Nitrate	**Nitrate**	**< 0.10 mg/Kg**	**Chlorides**	Promotes Stress Corrosion Cracking of Stainless Steels. Possible sources ..... Spent ion exchange resin or impure make-up water.
	Boron	**Boron**	**.......................**	**Nitrates**	Increased nitrate concentration in the water will result in increased production of D_2 & O_2. Its presence can be the result of poison addition (gadolinium) to the moderator water, exhausted ion exchange resin or it can also be caused by the presence of N_2 in the cover gas.
	Gadolinium	**Gadolinium**	**.......................**	**Boron**	Boron addition ..... no or little effect on D_2/O_2 production. Long term reactivity control ..... slow burnup rate. Difficult to remove by IX columns.
	%D_2O	**%D_2O**	**> 99.75%**	**Gadolinium**	High neutron cross-section ..... small concentration required fro reactor shut-down. Fast burn-up rate ..... about the same as
	Cover Gas %D_2, O_2 & N_2	**%D_2**	**< 4%**	Xe-135	.... used for Xe-135 simulation after start-up. Easily removed by IX columns (each column has enough capacity to remove Gd resulting from 2 LISS firings.
		%O_2	**< 2%**	**% D_2O**	Maintain high purity for efficient fuel burn-up. Also the % D_2O must remain high in order for the reactor to remain critical. 0.25 % downgrading will more than double the neutron cross-section of the moderator water. 1% downgrading will result in insertion of about 31.2 mK of negative reactivity (impossible to go critical at this value).
		%N_2	**< 2%**		

Moderator System Continued

System	Main Parameters Monitored	Chemistry Specifications	Comments
Main Moderator System			**% D_2, O_2, N_2** Levels of D_2 and O_2 monitored to ensure that explosive concentrations are not reached. A slight excess of O_2 is maintained in the cover gas to recombine with the D_2 the cover gas. Recombined to form D_2O in the recombiners. Nitrogen is not normally present in the cover gas. Its presence would indicate air inleakage (or impure helium make-up) into the system.

NUCLEAR SYSTEMS

System	Main Parameters Monitored	Chemistry Specifications	Comments
Primary Heat Transport System	**pH** **Specific Conductivity** **Lithium** **Dissolved Oxygen** **Dissolved D_2** **Chloride** **Fission Products (!-131)** **% D_2O** **%D_2, O_2 & N_2**	**pH** 10.2 - 10.8 **Specific Conductivity** 1.4 - 3.5 mS/m **Lithium** 0.5 - 2.0 ppm **Dissolved O_2** 10 ppb **Dissolved D_2** 3.0 - 10 ml/Kg **Chloride** < 0.10 mg/Kg **I-131** < 500 MBq/L **% D_2O** > 97.5 % **%D_2** 4% **O_2** 1% **N_2** 6%	**pH** Minimum carbon steel corrosion in this pH range. Corrosion rates increase at pH values above and below this optimum. pH adjusted by the addition of Lithium Hydroxide. Maintained by Li based ion exchange resin. **pH, Lithium & Specific Conductivity** Each of these parameters are related to one another. A given lithium concentration will correspond to a given system pH and specific conductivity. Deviations from this relationship would indicate the presence of impurities. **Dissolved O_2** Dissolved O_2 must be maintained low as the corrosion rate of carbon steel will greatly accelerate in its presence. Maintained low by H_2 addition to the system .... see below. **Dissolved D_2** H_2 added to the system to maintain dissolved D_2 in proper range. Added to the system in order to suppress O_2 formation via radiolysis. Too much could induce hydriding of the pressure tubes (imbrittlement). **Chloride** Stress Corrosion Cracking .

Primary Heat Transport System Continued

System	Main Parameters Monitored	Chemistry Specifications	Comments	
Primary Heat Transport System			**I-131**	I-131 concentration is maintained ALARA in the PHT system. Gives an indication of fuel failures. Controlled by removal of defective fuel from the system and by maintaining flow rate through the purification circuit. If I-131 concentration reaches 500 MBq/Kg, reactor shut-down must be initiated.
			% D_2O	Less efficient fuel burn-up as the isotopic decreases. Isotopic not as critical in this system as it is in the Main Moderator System. A decrease in the HTS isotopic down to 95% would result in about 5 mK of negative reactivity.
			%D_2, O_2, N_2	Levels of D_2 & O_2 maintained low to ensure explosive concentrations of these gases are not reached. The presence of N_2 would indicate air inleakage. The presence of N_2 in the cover gas would result in the formation of nitrates and nitric acid in the PHT water. This places an extra load on the PHT IX columns as well as increases the radiolytic breakdown of the D_2O.

System	Main Parameters Monitored	Chemistry Specifications	Comments
Annulus Gas System	**Dewpoint** **Gamma Nuclides** **D_2** **O_2** **N_2** **Tritium**	**Dewpoint** **-10^o C** **D_2** **1000 uL/L** **O_2** **0.5%** **N_2** **no spec. Indication of air in leakage.** **Gamma Nuclides** **no spec.** **Indication of PHT in leakage.** **Tritium** **no spec. Indication of PHT in leakage.**	**Dewpoint** Detection of leaks from a pressure tube, calandria tube or from the end shield cooling. Under normal conditions (no leaks), a small amount of D_2 will diffuse through the pressure tubes into the annulus gas (D_2 from the PHT system). This D_2 will react with the CO_2 (annulus gas) to form carbon monoxide and D_2O. Over time the D_2O concentration in the annulus gas will slowly increase. This increase in D_2O concentration will result in an increase in the dewpoint. When the dewpoint specification is reached, the system is purged with fresh CO_2. **D_2** System is purged with fresh CO_2 if high levels of D_2 are detected. High D_2 concentrations may cause hydriding of the Zirconium tubes. **O_2** High concentration of O_2 indicate air in leakage. System is purged with fresh CO_2 when high levels of O_2 are detected. **<u>NOTE:</u>** It is advantageous to maintain low levels of O_2 in the annulus gas system. Low levels of O_2 are necessary to maintain and replenish the oxide layer on the outer surface of the pressure tubes. This oxide layer is to maintained on the outside of the pressure tubes in order to prevent tube corrosion (impermeable layer .... prevents D_2 pickup by the tubes .... hydriding).

System	Main Parameters Monitored	Chemistry Specifications		Comments
Shield Cooling System	**pH** **Specific Conductivity** **Lithium** **Chloride** **% H_2** **% O_2**	**pH** **Specific Conductivity** **Lithium** **Chloride** **% H_2** **% O_2**	**10.0 - 10.5** **2.5 - 7.5 mS/m** **1.0 - 2.2 mg/Kg** **2.0 mg/Kg (max.)** **4.0 %** **2.0 %**	The objective of Shield Cooling chemistry is to minimize corrosion of system components and to remove activated products from the system. The main structural materials of the shield cooling system is carbon steel. Thus a high pH is maintained in order to maintain the magnetite layer and to minimize corrosion. A correlation exists between pH, Lithium concentration and Conductivity. Any deviation from this theoretical correlation would indicate the presence of impurities in the system. Cover gas % H_2 & O_2 concentrations are maintained below explosive concentrations by purging the cover gas with fresh nitrogen. If the system is to be shutdown for an extended period of time (> 30 days), hydrazine would be added to the water in order to remove dissolved O_2 and to maintain the magnetite layer on the carbon steel components.

System	Main Parameters Monitored	Chemistry Specifications		Comments
Liquid Zone Control System	**pH** **Specific Conductivity** **Chloride** **% H_2** **% O_2** **% N_2**	**pH** **Specific Conductivity** **Chloride** **Fluoride** **% H_2** **% O_2** **% N_2**	**5.5 - 8.0** **0.30 mS/m (max.)** **0.3 mg/Kg (max.)** **0.1 mg/Kg (max.)** **4.0 %** **2.0 %** **2.0 %**	Liquid Zone Control chemistry objectives: 1. minimize corrosion of components 2. minimize radiolysis of the water 3. maintain reactivity worth of the zones (impurities will absorb neutrons thereby creating errors in the known worth of the zones). System is mainly stainless steel and Zircoly-2 alloy. A neutral pH is maintained. Chlorides are maintained ALARA due to the stress corrosion cracking that is caused by the presence of this ion in contact with stainless steels. Fluoride ion is corrosive to the zircoly-2 alloy. Recombination Units and system purging with fresh Helium maintains the H_2 & O_2 below explosive concentrations.