Deviation	Causes	Unmitigated Consequences	Consequence Category	Likelihood	Risk Ranking	Recommendations
More Flow	Hydrogen/oxygen control valve failed fully open	Cell reaction pressure drop,Electrolysis efficiency will be	Business Loss	Middle	Low	1.Add high flow alarm to response
	Cooling Water hand valves fully open by human error	No Hazard identified				
	Caustic control valve failed to fully open	High level in cell, lead to overpressure,potential fatality	Safety	Low	High	1.Add high level alarm to response; 2. Add high high level interlock to trip reaction cell.
	Feed water valve fully open by human error	High level in sperator, lead to water be carried to next procee stage, H2 production unqualified	Business Loss	Low	Low	1.Add high level alarm to response;
	Nitrogen hand valve open by human error	Production unqualified.	Business Loss	Low	Low	1.Add blind flange between the two hand valves.
Less Flow	Hydrogen/oxygen control valve failed fully close	Overpressure lead to vessel/cell rupture potential fatality	Safety	Low	High	1.Add high Pressure alarm to response; 2. Add high high Pressure interlock to trip reaction cell.
	Cooling Water hand valves fully close by human error	Water carried with H2/O2,production unqualified	Business Loss	Low	Low	1.Add high temperature alarm for the production to response
	Caustic control valve failed fully closed	Low level in cell, lead to reaction stop	Reliability	Low	Low	1.Add Low level alarm to response.
	Feed water valve fully closed by human error	Low level in cell, lead to reaction stop	Reliability	Low	Low	1.Add Low level alarm to response.
	Pump Failure	Backflow of gases,causing flammable gas mixture	Safety	Low	High	1.Use valves to prevent gas backflow
	Facility Leakage	Hydrogen leak into facilities, risk of explosion	Safety	Low	High	1.Install hydrogen sensor and leak alarm for emergency shut down
	Valve or pipe blockage	Bursting of pipes	Safety	Low	High	1.Install blockage detectors
	Water level too low	Leakage current	Safety	Low	High	1. Check the level controller
No flow	Refer to less flow					

Deviation	Causes	Unmitigated Consequences	Consequence Category	Likelihood	Risk Ranking	Recommendations
Reverse Flow	Caustic source shut down due to unkown reason	Hydrogen reverse to caustic system,cause jet fire if leaked,potential people injury	Safety	Low	Middle	1.Add check valve.
	Feed water source shut down due to unkown reason	Hydrogen reverse to feed water system,cause jet fire if leaked,potential people injury	Safety	Low	Low	1.Add check valve.
High Pressure	Pressure control system fails;Blockage; Pump failures	Facilities breakdown, potential explosion; low gas purity	Safety	Low	High	1. Pressure sensor installed for emergency shutdown
Low Pressure	Pump fails; pressure controls fails; leak in reactor	Electrolyte boils if operating above 100 °C; more work at hydrogen storage stage	Safety	Low	Middle	1. Check the pumps; 2.Check for any leakage
High Temperature	Cooling water flow rate too low; Heat exchanger malfunction	Material corrosion and mechanical failure such as membrane rupture; Electrolyte boiling	Safety	Low	High	1.Check the cooling water valves 2. Check temperature controller
Low Temperature	Cooling water flow rate too high; Heat exchanger malfunction	Low efficiency	Business Loss	Low	Low	1.Check the cooling water valves 2. Check temperature controller
Rupture/Leak	Tube rupture in cooler	Cooling water side overpressure due to Hydrogen mixing, cause jet fire if leaked,potential people injury	Safety	Low	Middle	1.Add pressure relieve valves
Contaminants/ Composition	Water deionization stage malfunction	Side reactions; reduce lifetime	Safety	Low	Middle	1. Add anaylser for feed water quality
Chemical Hazards	Electrolyte concentration too high	Cell or pipeline leakage due to corrosion;corrosion of membrane and electrodes	Safety	Low	High	1.Upgrade materials. 2. Check recirculation pump 3.Install PH meter linked to alarms