Co-location of Hydrogen Plants and Other Industrial Plants Near Nuclear Reactors






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Nuclear reactors make steam, which is then used to produce electricity. But steam can also be used in various industrial processes, reducing the need to burn fossil fuels, a national policy goal. One such process is making hydrogen cleanly, through electrolysis, another national policy goal, which can be achieved using electricity and/or heat from nuclear reactors. Making hydrogen with electrolysis can replace hydrogen from methane reformation, a method that results in carbon dioxide (CO_2) emissions.

Electricity is easy to transport but steam is not, so a nuclear power reactor and an industrial plant must be located within some proximity to each other. A new risk analysis created by LWRS Program researchers at INL and SNL shows hydrogen production is safe at a short distance from a nuclear power plant.

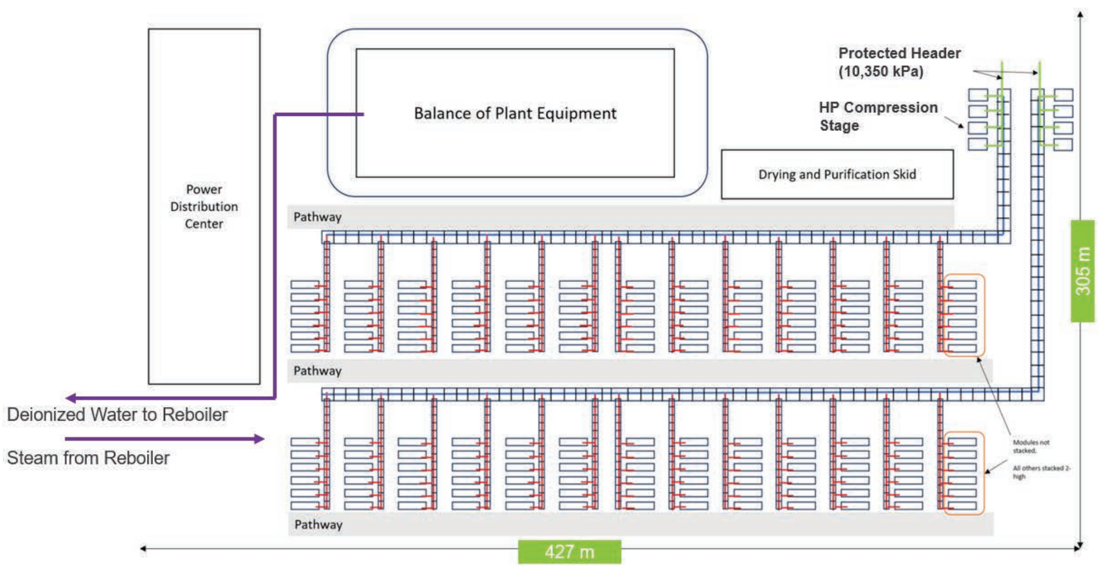

Figure 10. High-Temperature electrolysis facility layout.

The LWRS Flexible Plant Operation and Generation program continues to lead the way in safety research for siting industrial facilities near nuclear power plants. In 2023, laboratory researchers worked closely with representatives of the hydrogen and nuclear industries, along with regulators, through the LWRS Program's Hydrogen Regulatory Research and Review Group (H3RG) to assess safety hazards applicable to nuclear power plants supporting a hydrogen facility [1]. The participants identified the three most likely sizes for a high-temperature electrolysis facility (HTEF) at 100, 500, and 1000° $MW_{nominal}$ power. Sargent and Lundy, the architectural engineering firm, worked closely with the INL risk assessment team on the HTEF design, as shown in Figure 10, as well as the corresponding thermal extraction system for the reactors.

The HTEF specifications allowed for more precise assessment of the two major co-location risks: (1) heat from fire, and (2) deflagration/detonation overpressure. Heat flux determines the minimum safe distance between the HTEF and nearby structures and vegetation. If hydrogen leaks from a pipe or a tank and ignites and burns rapidly in a process called deflagration, the result is a pressure wave. Detonation, or the explosion of hydrogen, also produces a pressure wave. The U.S. Nuclear Regulatory Commission (NRC) prohibits locating an explosive source that would produce an overpressure exceeding 1.0 pound per square inch gauge (PSIG) at any nuclear plant safety system, structure, or component [3]. A 1.0 PSIG overpressure is enough to shatter glass [3].

The team analyzed the safety risk to the nuclear power plant using two methods: (1) deterministic, and (2) probabilistic. The deterministic analyses calculated the distance at which the overpressure from a detonation or deflagration would dissipate to 1.0 PSIG. To make this calculation, hydrogen explosion experts used the HTEF specifications to determine hydrogen volume and pressure throughout the facility. Then, they determined the amount of hydrogen available for an explosion based on the plume of the hydrogen leak.

The team used the hydrogen detonation overpressure and fire regulation standards from the National Fire Protection Agency (NFPA) [4] to determine the safe standoff distances for explosions and fires. A siting analysis was performed for several representative sites, which showed that an HTEF could be placed safely within the hydrogen facility boundary dictated by the NFPA approximately 21 meters away from the perimeter of the nuclear power plant in all cases by orienting the higher explosive risks further away from the plant, as indicated in Figure 11.

Figure 11. Safe standoff distances from a nuclear power plant to a HTEF.

The INL risk assessment team modeled the hardware changes required to extract steam from a nuclear power plant in a probabilistic risk analysis (PRA). All nuclear plants have PRAs, which estimate the initiating events of accidents and safety system performance that prevent an accident from causing damage to the nuclear fuel. For this analysis, experts added the steam extraction system and connection feeding electricity directly to the hydrogen plant in the PRA. The evaluation of these modifications was required because they increased the frequencies of possible initiating events and their consequences. The conclusion of the PRA [1] was that under the NRC rules in 10 CFR 50.59 [5] covering power plant modifications, a hydrogen production facility could be safely added if the safe standoff distances are met.

In 2024, the risk assessment team has continued working with the LWRS and Integrated Energy Systems Program to focus on other industrial processes that may be supported by nuclear power plants beyond hydrogen and the hazards they present. Hazard and risk analyses are being performed for facilities to produce methanol, oil refining, synthetic fuels, and wood pulp and paper. In addition to explosion or fire, the hazards being assessed include the release of toxic, corrosive or caustic materials, and non-toxic pollution.

References

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