Nuclear Services / Engineering Services

Integrated Hydrogen Control Solutions for Severe Accidents Using Passive Autocatalytic Recombiners

Background

Recent industry events have highlighted the importance of understanding, controlling and mitigating the effects of hydrogen (H_2) generation under accident conditions. The ability to control and mitigate H_2 generation, first and foremost, protects the health and safety of the public and plant personnel; it also preserves the nuclear asset.

In a severe accident or a beyond-design-basis accident (BDBA), the reaction of water with zirconium alloy fuel cladding, radiolysis of water, molten corium-concrete interaction (MCCI) and post-accident corrosion can generate H_2. The total mass of H_2 produced in-vessel depends on several factors; for most reactors, it is approximately 1,000 kilograms. High peak rates of up to several kg/s for release to containment can result from sporadic releases from the reactor pressure vessel. If this leads to the detonation of H_2, personnel and public safety are threatened and various structures can be damaged, including containment and spent fuel buildings. To avoid this risk, passive autocatalytic recombiners (PARs) can be implemented in various reactor designs.

Description

H_2 control is a complex problem, and without an integrated approach, the solution can be expensive and time-consuming. Westinghouse provides streamlined technical solutions designed to fit plant-specific needs.

H_2 Generation and Distribution Analysis

Westinghouse performs analyses to define the quantity, transport and distribution of H_2 to identify locations requiring new and/or updated H_2 mitigation hardware.

- A large number of simulations are performed using global analysis tools to determine the H_2 generation source code. Integral codes such as the MELCOR code or the MAAP code form the basis for these analyses and are used to identify the accident scenarios that reflect the greatest threats to the containment or spent fuel buildings.
- The next step consists of using global analysis tools to define H_2 distribution and transport by performing detailed calculations with specialized codes used to characterize H_2 distribution and transport, such as the MAAP code, GASFLOW code or FATE™ code.
- The last step in the analyses is to determine the optimum PAR configuration, with respect to the number, size and location of the PARs, for mitigation of H_2 risks.

H_2 Management System Design

Westinghouse evaluates and selects hardware options for increased H_2 control and monitoring, including the appropriate PARs.

- PARs come with various H_2 depletion rates, footprint sizes, and exhaust heights and forms. This supports integration into existing plants and optimization of the overall concept.
- Non-passive equipment, such as igniters, can also be used in an integrated H_2 control system.
- H_2 monitoring can be incorporated into an integrated H_2 control system.

H_2 Mitigation and Monitoring Hardware

Westinghouse performs the engineering – including creating the design change package (DCP) – licensing, procurement and installation of a new and/or upgraded hardware solution.

Westinghouse manufactures and installs H_2 control equipment in cooperation with experienced partners. Westinghouse offers a complete customer-specific package:

- Choice of a specific equipment configuration
- Licensing/DCP support
- Delivery and installation of the equipment

Westinghouse

June 2014 NS-ES-0217

Procedure and Guideline Upgrades

Westinghouse will create and/or update existing procedures and guidelines as appropriate.

Westinghouse will:

- Evaluate current procedures and guidelines for inclusion of H_2 control
- Identify and implement upgrades to existing procedures and guidelines (e.g., emergency operating procedures, emergency response guidelines and severe accident mitigation guidelines)

Benefits

The Westinghouse system offers demonstrated startup at the lowest levels of H_2 concentration in the industry. By initiating earlier, the Westinghouse system provides the operators and safety systems more time to respond to the accident conditions before the point of flammability is reached. In addition, our housing design is optimized to achieve maximum flow rates to promote atmosphere mixing.

The PAR offered by Westinghouse is certified by the U.S. Nuclear Regulatory Commission for power plants in the United States. Westinghouse offers:

- Global technology resources to meet customer and regulatory needs on a local basis:
  - Little-to-zero maintenance costs throughout the life of the equipment
  - Testing of multiple cartridges to expedite required tests, shortening work time during outages
  - Depletion rates designed to protect against approaching the point of flammability
  - Elimination of all containment penetrations associated with H_2 control, thus eliminating penetration testing
- Proven experience in H_2 control and mitigation
- Graded approach using integrated solutions covering analysis, procedure and hardware options to provide cost savings
- Completely passive equipment (e.g., PARs) can be used:
  - High reliability (no power source is necessary)
  - Robust with respect to atmospheric conditions or mechanical (seismic) loads (no moving parts)
  - Simple to install and maintain
  - Solution for control of H_2 generated by radiolysis effects even in inert boiling water reactor (BWR) containments
  - Application for design-basis accident (DBA) and BDBA (replace active systems for H_2 mitigation for DBA)
  - Can be installed in wet-fuel assembly storage pools and in used-fuel areas

Experience

Westinghouse and its partners have proven experience in H_2 control and mitigation and offer integrated solutions for utilities that desire to simplify hardware, design, analysis, procedures and installation procurement for H_2 control solutions for the following:

- Large dry containments
- Ice condenser containments
- Replacement of thermal recombiner systems to minimize in-service testing in the United States
- BWR containments in the United States and Japan
- BWRs and pressurized water reactors (PWRs) in Germany
- PWRs in South Africa, South America and Europe
- Voda-Voda Energo Reactor containments
- New plant designs (**AP1000®** PWRs and advanced BWRs)

The operational experience of approximately 20 years for PAR systems in several plants has proven the high reliability and low maintenance of the equipment.

The PARs used by Westinghouse have successfully participated in numerous international test programs for qualification, for example:

- Nuclear Instrumentation System PAR qualification for the U.S. Nuclear Regulatory Commission at Sandia National Laboratory in the United States
- Electric Power Research Institute/EDF test in the KALI-H_2-test facility of the CEA Cadarache facility in France
- EDF/IRSN test PHEBUS-FPT3 in the Cadarache facility in France
- OECD test in the THAI-test facility in Frankfurt, Germany

Additionally, PAR systems have been installed in wet-fuel assembly storages and used-fuel transportation caskets for the control of H_2.

- Westinghouse is the leader in software analysis for H_2 generation and transport.
- Westinghouse has in-depth understanding of the MAAP and FATE codes and wrote the original code for each.

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

www.westinghouse**nuclear**.com