Nuclear Services/Engineering Services

Integrated Hydrogen Monitoring Solutions for Severe Accidents

Background

During 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 hydrogen (H_2). The total mass of H_2 produced in-vessel depends on several factors. For most reactors, it is on the order of 1,000 kilograms. High peak rates for H_2 release to the containment of up to several kg/s can result from discontinuous releases from the reactor pressure vessel. The detonation of H_2 can result in damage to structures such as containment buildings or spent fuel buildings. In all reactor designs, H_2 monitors can be utilized to monitor the risk of containment or spent fuel building damage due to H_2 detonations.

Recent industry events highlighted the importance of understanding and monitoring the effects of H_2 generation under accident conditions. The ability to monitor H_2 generation in the containment and spent fuel buildings provides vital information to plant operators that can be used to assess the progression of an accident, as well as to assess the safety of these buildings.

Westinghouse has proven experience in H_2 monitoring and offers an integrated solution for utilities that desire to simplify procurement of the hardware, design, analysis, procedures and installation. The Westinghouse H_2 monitoring solution can be integrated with the Westinghouse H_2 control solution.

Why Westinghouse?

The Westinghouse system allows an in situ arrangement, which does not require the sample lines, containment isolation valves and compressors/vacuum pumps associated with gas transport H_2 monitors. An in situ arrangement reduces the cost and maintenance associated with installing this additional equipment and eliminates the need for containment penetration testing at the sample lines.

Description

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

Perform Analysis of H_2 Generation and Distribution

Define quantity and transport/distribution of H_2. Identify locations requiring new/updated H_2 monitoring hardware.

- Utilize global analysis tools to determine H_2 generation source term:
  - The basis for the analysis is a large number of simulations using a code such as the MELCOR code or the MAAP code, which are utilized to identify the accident scenarios posing the highest threat to the containment or spent fuel building.
- Utilize global analysis tools to define H_2 distribution and transport:
  - The next step consists of detailed calculations with a code such as the MAAP code, GASFLOW code or FATE™ code, specialized codes used to characterize H_2 distribution and transport.
- This analysis is used to determine the optimum configuration for the H_2 monitoring sensors.

Design H_2 Monitoring System

Evaluate and select hardware options for increased H_2 monitoring.

- Evaluation and selection of H_2 monitoring options:
  - Analysis to identify inadequacies in existing monitoring system, if the plant is upgrading
  - Location of primary processing system
  - Evaluation of computer interface options (e.g., stand-alone system, control room display, choice of annunciators)

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Example of an H_2 sensor

- H_2 monitoring can be integrated with the H_2 control system design utilizing a single evaluation with the analysis tools described above:
  - The first steps in developing an H_2 monitoring system and an H_2 control system are similar, so the same steps can be used for both system designs

Engineer and Install H_2 Monitoring Hardware

Perform engineering, including design change package, licensing, procurement and installation of new/upgraded hardware solution.

The manufacture and installation of equipment for H_2 monitoring is performed by Westinghouse in cooperation with experienced partners. Westinghouse offers a complete customer-specific package:

- Choice of a specific equipment configuration
- Licensing support
- Delivery and installation of the equipment
- Control room display and annunciator interface
- Implement procedure and guideline upgrades
- Evaluation of current procedures and guidelines for inclusion of the H_2 monitoring system
- Identification and implementation of upgrades to existing procedures and guidelines (e.g., Emergency Operating Procedures, Severe Accident Management Guidelines or Emergency Response Guidelines)

Benefits

- Global technology resources to meet customer and regulatory needs on a local basis
- Graded approach using integrated solutions covering analysis, procedure and hardware options to provide cost savings
- The H_2 monitors used in the system provide distinct advantages. Some features of the monitoring system include:
  - No reagent or nitrogen zero gas flows are required for operation of the analyzers
  - The analyzer operates at containment pressure requiring no pressure control or regulation
  - H_2 monitors will be placed in an in situ arrangement, which provides the following advantages over gas transport monitors:
    - No sample line, containment isolation valves, compressor/vacuum pump or controls are required for transportation of the sample
    - No sample line containment penetration is required, eliminating containment penetration testing
  - H_2 concentration is measured using multiple monitors capable of sensing concentrations in the range of zero to 20 percent by volume, with an accuracy of ±2 percent of scale
  - H_2 sensors require calibration only after each outage
  - Manual adjustments are minimized
  - No custom circuitry; all conditioning modules are standard designs
  - Control assembly can be located remotely, allowing for the operation, monitoring and management of the sensors from outside of containment
  - The programmable logic controller used within the remote control center is distributed worldwide for multiple industries, not just the nuclear power industry
  - The system incorporates a state-of-the art human-machine interface (HMI) in the form of a touch screen display with all screens arranged in a logical, intuitive manner
  - Maintenance costs are minimal, and operational reliability is maximized
  - System is designed to be used during design basis accidents (DBAs) and BDBA

Experience

Westinghouse and its partners have proven experience in providing in situ H_2 monitoring solutions for the following:

- Large dry containments
- New plant design (**AP1000**® pressurized water reactors)

Westinghouse has more than 20 years of experience in providing online monitoring systems and, thus, knows how to install and maintain online systems for optimal performance.

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

www.westinghousenuclear.com