Membrane-based Air Removal System

Background

Nuclear power plants have historically struggled to maintain dissolved oxygen levels within specification limits in the primary water storage tank (PWST) even though the PWST has provisions for excluding gas (dissolved air). High oxygen concentrations are suspected to adversely affect reactor coolant pump (RCP) seal leak-off performance. Concerns are known for the formation of radio-gases from dissolved nitrogen and argon ingress to the reactor coolant system (RCS). In addition, the presence of dissolved nitrogen from the air can result in the formation of ammonia, which can interfere with RCS pH control. These issues are magnified during the end-of-core cycle, when higher volumes of primary makeup water (PMW) are added to reduce RCS boron for core burnup.

Description

Westinghouse has developed an in-line, on-demand system to treat PMW via the chemical and volume control system (CVCS) makeup control system. Westinghouse's in-line, membrane-based air removal system (MARS) is shown in the images on the next page to demonstrate the process. In Figure 2, the system is in standby for operation, where treated water is initially returned to the PWST during system startup. When PMW is needed, such as for RCS boron dilution, signals from the CVCS automatic makeup control system automatically align the membrane system as shown in Figure 3. The dissolved gas-free water - where dissolved oxygen is less than 100 parts per billion (ppb) - is then sent directly to the existing PMW system supply line as normally used by the existing CVCS.

MARS is designed for air-saturated water; therefore, the gas permeability performance of the PWST bladder or diaphragm is not important for gas exclusion. The PWST, the pump and the line marked, "To CVCS Primary Makeup Water Line," shown in the images on the next page are already present in existing plant components and piping.

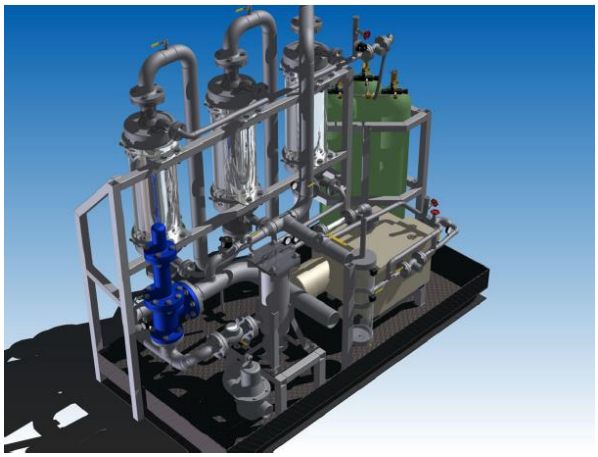

Figure 1: MARS Skid Rendition of Preliminary Design (4 ft x 8 ft x 7 ft high)

Benefits

• Automatically provides dissolved gas-free water (dissolved oxygen controlled to less than 100 ppb; nitrogen and argon are also removed) PMW to the CVCS makeup system. System operation is transparent to the control room operator.

• Does not rely on any reaction chemicals. There will be a very low residual of dissolved nitrogen (strip gas; about 2 ppm out of 21 ppm, or 90 percent nitrogen removal) depending on plant-specific design.

• Membrane technology efficiently removes dissolved gases for a water temperature range of 40°F to 100°F. This efficiency outperforms the traditional vacuum tower methods and provides a much smaller design and lower operating cost.

• The small membrane skid is self-contained such that an electrical power supply is all that is needed to operate the skid. The membranes and a vacuum pump are the only major pieces of equipment.

• The in-line, on-demand design does not rely on the gas exclusion performance of the PWST bladder or membrane. This may allow for relaxation or elimination of the PWST dissolved gas specification requirements.

• The skid is designed to interface with the Safety Class 3 PMW system. The skid itself is seismic (passive), non-nuclear safety-rated for simplified

equipment procurement, plant implementation and maintenance.

Experience

• Westinghouse sources a membrane-based degassing systems which assures a viable technology for removal of dissolved oxygen (O_2) from PMW.

• The selected membrane contactors are used around the world to remove dissolved gases in a wide variety of markets, including semiconductor, pharmaceutical, power, food and beverage, and inks. These components have been a proven technology for more than 25 years, with many individual systems in continuous operation for more than 10 years.

• Design work is ongoing to support proposals for two basic reference designs:

— Combination of vacuum with nitrogen-stripping gas to treat water from 40°F to 100°F

— Vacuum only to treat water from 70°F to 100°F.

MARS Plant Systems Interfaces

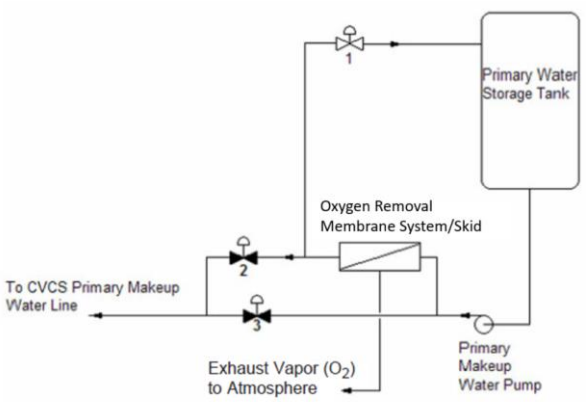

Figure 2: Fuel Burnup Boron Dilution Standby Alignment

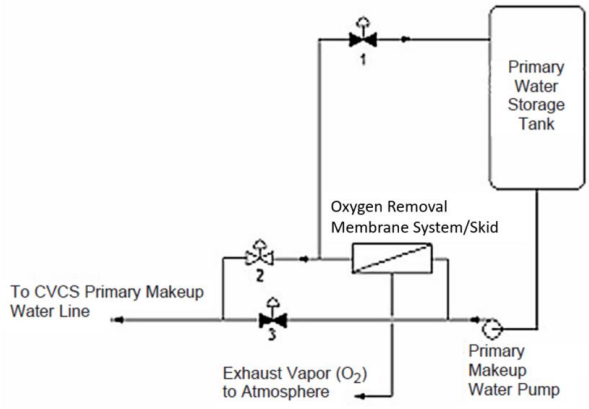

Figure 3: Fuel Burnup Boron Dilution Alignment

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