Nuclear Services/Engineering Services

# 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 seal leak-off performance. Recently, concerns about the formation of radio-gases from dissolved nitrogen and argon ingress to the reactor coolant system (RCS) have been identified. 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 a "reference design" for an in-line, on-demand system to treat PMW for the chemical and volume control system (CVCS) makeup control system. The in-line, membrane-based air removal system (MARS) is shown in the images on the next page to demonstrate the process. The first image shows the system in standby, where treated water is initially returned to the PWST during MARS startup. When PMW is needed, such as for RCS boron dilution or makeup for RCS leakage, signals from the CVCS makeup control system automatically align MARS, as shown in the dilution alignment image. 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 CVCS. The MARS reference design is intended to be flexible and can be used as the starting point for designing variations for plant-specific application.

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

## Benefits

- Automatically provides dissolved gas-free PMW (dissolved oxygen controlled to less than 100 ppb; nitrogen and argon are also removed) to the CVCS makeup system. System operation is transparent to the control room operator.
- Does not rely on any reaction chemicals. 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 only electrical power supply is needed to

MARS skid rendition of reference design
(4 ft x 8 ft x 7 ft high)

Westinghouse

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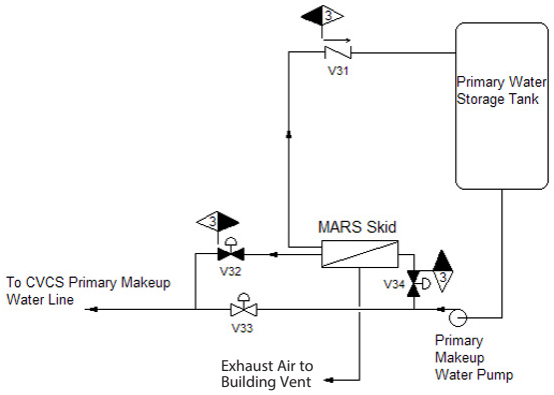
operate the skid. The membranes and a vacuum pump are the only major pieces of equipment.

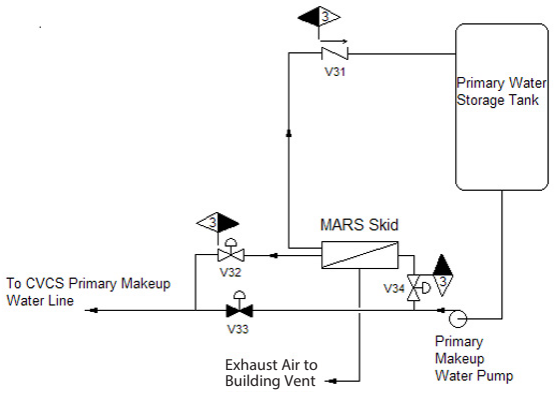
- The in-line, on-demand application does not rely on the gas-exclusion performance of the PWST bladder or membrane. This may allow for relaxation or elimination of the PWST dissolved-gas specification requirements.
- The skid is designed to interface with the Safety Class 3 PMW system. The skid itself is seismic (passive), non-nuclear safety-rated for simplified equipment procurement, plant implementation and maintenance. Normally closed, Safety Class 3 isolation valves are shown in the figure showing standby alignment.
- The MARS reference design is flexible and can be used as the starting point for designing variations for plant-specific applications.

## Experience

- Membrana, the membrane manufacturer, and Westinghouse have jointly determined that Liqui-Cel® membrane-based degassing systems are a viable technology for removal of dissolved air from PMW.
- Liqui-Cel Membrane Contactors are used worldwide to remove dissolved gases in a wide variety of markets, including semiconductor, pharmaceutical, power, food and beverage, and inks. The Liqui-Cel Membrane Contactor has been a proven technology for more than 20 years, with many individual systems in continuous operation for more than 10 years.
- The MARS reference design is complete, has been successfully tested and is available for plant-specific application.




Fuel burn-up boron dilution standby alignment




Fuel burn-up boron dilution alignment

*Liqui-Cel® is a registered trademark of Membrana-Charlotte, a division of Celgard, LLC.*

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