

## Measurement of Percent Hydrogen in the Mechanical Vacuum Pump in Gas Stream during BWR Startup

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### ABSTRACT

All U.S BWRs use a Mechanical Vacuum Pump (MVP) to establish condenser vacuum during startups, normally from the initial heatup to the point where sufficient reactor steam pressure and flow is available to place the Steam Jet Air Ejector (SJAE) and offgas treatment system in service. MVP operation is restricted to <5% power and gas stream concentrations of <4% H<sub>2</sub>, the lower flammability limit (LFL) for hydrogen/air mixtures. For a particular plant startup prior to hydrogen injection for hydrogen water chemistry (HWC), the MVP %H<sub>2</sub> would depend on the air inleakage rate, the hydrogen gas generation rate from radiolysis and the gas/steam transport rate from the reactor vessel to the main condenser. The radiolysis rate at low power, which is not precisely known and has not been modelled for the BWR, is normally assumed to increase in proportion to thermal power. Two thirds of the radiolytic gas by volume would be hydrogen and one third oxygen. The MVP is not equipped with hydrogen sampling and measurement capability, and many MVP systems include no flow measurement. No U.S plant or literature data on MVP %H<sub>2</sub> were found.

The industry-first Early Hydrogen Water Chemistry (EHWC) demonstration at the Peach Bottom 3 nuclear power plant involved hydrogen gas injection into the reactor vessel during startup while the MVP was in service. To support the EHWC project, it was necessary to collect baseline MVP %H<sub>2</sub> data during a startup without hydrogen injection and to monitor MVP %H<sub>2</sub> during the startup with EHWC. The MVP system had no normal sample point, but included test taps in the suction and discharge piping. A sampling method and apparatus was invented (patent pending), designed, built and applied to obtain hydrogen measurements in the MVP gas stream. The apparatus allowed a gas sample stream to be taken from either the suction (vacuum) or discharge side of the MVP. The gas sample stream was preconditioned to remove moisture (the MVP uses water as a liquid compressant), flowed to a %H<sub>2</sub> sensor and was returned to the system. Hydrogen analyzer results were captured using a digital data recorder.

MVP %H<sub>2</sub> data were collected during the Peach Bottom 2 startup in October 2010 (baseline, no hydrogen injection) and during the Peach Bottom 3 startup with EHWC in October 2011. The October 2010 baseline results were the first known MVP %H<sub>2</sub> measurements and provided indications of the hydrogen generation rate from radiolysis at low power. Comparison of the October 2011 results with EHWC and the baseline results show the impact of hydrogen injection on MVP %H<sub>2</sub>. The results were also compared with radiolysis gas generation rate correlations, specifically the ANSI/ANS Standard 55.4-1993 design rate of 0.06 standard cubic feet per minute per mega-watt thermal (scfm/MWt) and the average rate based on measurements at a number of plants under power operating conditions of 0.041 scfm/MWt.