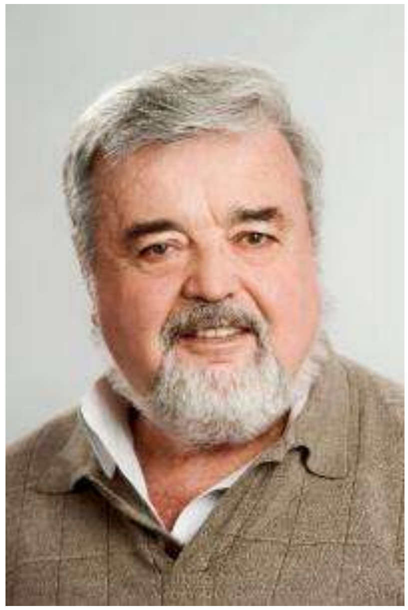

TRIBUTE TO PROF. DIGBY MACDONALD

November 17, 2025 (Peter Tremaine, Rajeev Gupta, Barry Dooley and David Shoesmith)

The Canadian and American Committees for the Properties of Water and Steam mourn the loss of Professor Digby D. Macdonald who passed away on June 11, 2025, at the age of 81, at the UC Davis Hospital in Sacramento, CA.

Digby D. Macdonald was a native of New Zealand, a naturalized US citizen, and a Professor in Residence (semi-retired) in the Departments of Nuclear Engineering and Materials Science and Engineering at the University of California at Berkeley. He has published more than 1000 papers in peer-reviewed journals and conference proceedings and has published four books. He is a Fellow of the Royal Society of Canada and the Royal Society of New Zealand, in addition to Fellowships of numerous professional societies and recipient of many other honours and awards. In 2013 he was awarded the prestigious IAPWS Gibbs Award for his substantial contributions to the development of knowledge on the properties of aqueous solutions at high temperatures and pressures, and to fundamental electrochemical and corrosion science in areas related to electric power generation.

Upon completion of his PhD (Univ. Calgary) in 1969, Dr. Macdonald joined Atomic Energy of Canada's (AECL) Whiteshell Nuclear Research Establishment (WNRE) at Pinawa, Manitoba. At the time he began his career, the science of high-temperature aqueous chemistry and electrochemistry were in their infancy. Except for some work on secondary coolant chemistry at CEGB Leatherhead, UK, and fundamental studies by Marshall, Baes, Mesmer and their co-workers at the Oak Ridge National Laboratory (ORNL) using hydrogen concentration cells, almost no work was being performed worldwide on the application of electrochemical principles to understanding corrosion and activity/mass transport phenomena in primary and secondary coolant circuits of nuclear and feedwater as well as boiler water systems of fossil steam generating plants.

Prof. Macdonald's research at AECL, and later positions at Stanford Research Institute (SRI), University of Ohio and Penn State has been instrumental in advancing our understanding of the unique chemical and electrochemical processes that occur in aqueous environments at elevated temperatures. These contributions include pioneering work at AECL to develop among the first

Pourbaix thermodynamic stability diagrams to map the areas where corrosion can occur in reactor coolant systems at operating temperatures, and contributions to monitoring and controlling activated corrosion product transport in CANDU nuclear reactor primary coolant circuits. He invented the technology for pressure-balanced reference electrodes in which reference electrodes, required for electrochemical measurements in high-temperature water, can be maintained at controlled ambient conditions, yet are coupled to the corrosive solution in high temperature electrochemical cells. He also developed the sophisticated equations for liquid junction potentials, based on non-equilibrium thermodynamics, required to carry out quantitative measurement with these pressure-balanced reference cells. Related research developed some of the first practical high-temperature pH and reference electrodes for research and power station applications. Some of these have seen widespread use in research labs, large-scale high-temperature loops used for engineering studies, and in novel nuclear reactor hydrogen sensors.

Using these techniques, Prof. Macdonald became one of the pioneers in developing methods for applying cyclic voltammetry and AC-impedance spectroscopy to study electrochemical and corrosion processes *in situ*, at high-temperature power station coolant conditions. Because of the corrosive nature of high-temperature aqueous systems, the challenges in developing these methods were formidable. They were achieved through Prof. Macdonald's insightful experimental designs and innovations, and they are a very significant contribution to the field. In basic research, his work has shed light on the thermodynamics and kinetics of complex electrochemical reactions, and the formation and stability of various chemical species under these extreme conditions. Applications of his research have encompassed such diverse areas as hydrothermal synthesis, supercritical water oxidation and, especially, high-temperature aqueous corrosion.

Professor Macdonald's later contributions include the development and application of several critical models, including the Point Defect Mixed Potential Model (PDM), Coupled Environment Pitting Model (CEPM), Coupled Environment Fracture Model (CEFM), and Coupled Environment Corrosion Fatigue Model (CECFM). These models have significantly enhanced our understanding of corrosion processes and have found extensive applications in the nuclear industry and more generally in systems where corrosion can be an issue. Furthermore, his research group has developed codes for predicting the products resulting from the radiolysis of water. By combining these codes with the afore-mentioned models, they have successfully predicted accumulated corrosion damage, such as crack length, along the Corrosion Evolutionary Path - the operational history of the reactor. These predictive capabilities have provided invaluable insights into corrosion behavior, enabling the development of effective mitigation strategies and improvements to the overall safety and reliability of reactor coolant circuits. To date, these codes have been applied to 15 Boiling Water Reactors (BWRs) and 2 Pressurized Water Reactors (PWRs). Most recently his models were applied to the coolant circuit of the ITER fusion technology demonstration reactor that is currently being built in Cadarache, France. He also contributed to developing the science base for the disposal of High-Level Nuclear Waste in the US (Yucca Mountain), Belgium, and Sweden.

In research particularly relevant to IAPWS, Professor Macdonald determined how stress corrosion and corrosion fatigue cracks are initiated and grow in the Phase Transition Zone (PTZ) of fossil and nuclear steam turbines from the pits and microcracks which are precursors to failure/damage. These are the major failure mechanisms in steam turbines worldwide. He used practical and theoretical applications of his Point Defect Model to develop the first quantitative understanding of why providing dehumidified air to the PTZ in the Low-Pressure Steam Turbine during the shutdown leads to a marked reduction in the probability of failure/damage. This work has subsequently become the basis of damage prevention for the main failure mechanisms and is a key part of IAPWS's Steam Purity Technical Guidance Document.

Throughout his career, Prof. Macdonald's work was characterized by exceptional research skills, analytical prowess, innovative thinking, and a deep understanding of the underlying principles governing corrosion phenomena. Moreover, his ability to effectively collaborate with interdisciplinary teams and to mentor junior researchers was exemplary. His success set the standard for the approach now used by many electrochemistry/corrosion groups in the nuclear energy sector, which is based on top-flight mission-oriented scientific research, insightful selection of problems, and open publication to the greatest extent possible.