IAPWS Canadian National Committee

Annual Report 2013

Submitted at ICPWS16, Greenwich, UK, Sept. 6, 2013

Executive: *David Guzonas (IAPWS Vice President, member-at-large); William Cook (Chair); Derek Lister (Secretary-Treasurer); Peter Tremaine (Member at Large); Melonie Myszczyszyn (Member at Large); Steve McGee (CANDU Owners Group Representative)*

1. Canadian National Committee: Dues for the Canadian National Committee (CNC) of IAPWS are supported by the National Research Council of Canada. This arrangement requires support and participation by a national organization representing industry. In 2004 the CANDU Owners Group took on this role on a trial basis, and in 2007 the CANDU Owners Group accepted this role for a five-year term, including travel support for the academic members of the CNC. In December 2012, chairman Guzonas meet with the CANDU Owners Group and was able to secure this essential industry support for the CNC for the next five years.

Due to his role as the chair of the Joint Committee on the Properties of Seawater, Prof. Rich Pawlowicz (University of British Columbia) has agreed to sit on the CNC as a member-at-large.

Dr. Dave Guzonas accepted the CNC nomination to be Canada's choice for IAPWS vice-president for 2013-2014. He will transition to IAPWS president for 2015-2016. Prof. William Cook accepted the CNC nomination to become chair of the CNC due to the vacancy left with Dr. Guzonas' promotion.

2. NSERC/NRCan/AECL Generation IV Energy Technologies Program

A major university-based program to study water chemistry in support of the development of the Canadian Supercritical Water-cooled Reactor concept (NSERC/NRCan/AECL Generation IV Energy Technologies Program) is currently in Phase II and includes seven water chemistry projects that cover two main themes: a) corrosion product transport and deposition, and b) water radiolysis. The goal is to develop chemistry control strategies for the SCWR as well as recommend realistic chemistry conditions for corrosion testing for materials selection. The program also funds eight projects examining materials degradation phenomena (e.g., corrosion, stress corrosion cracking, creep) at temperatures up to 850 ºC. The yearly workshop for the program members was held in Toronto in June 2013.

Research on high-temperature water chemistry being funded by this program includes:

P. Tremaine (U. of Guelph): Aqueous chemistry of metals and fission product under SCWR conditions.

C. Pye (St. Mary's University): Ab initio calculations on ionic hydration and complexation.

W. Cook (U. of New Brunswick): Corrosion product transport and deposition under SCWR conditions.

I. Svishchev (Trent University): Water chemistry, pH control and particle formation process in an SCWR.

A. Anderson (St. Francis Xavier University): Time-resolved investigations of metal oxide-water systems under conditions of extreme temperature, pressure and radiation.

P. Percival (Simon Fraser University), K. Ghandi (Mount Allison University): Reaction kinetics in SCW probed using muonium.

J.-P. Jay-Gerin (U. of Sherbrooke): Computational modelling of water radiolysis in high temperature water (including SCW).

C. Wren (U. of Western Ontario): Water radiolysis effects on materials degradation in high temperature water (including SCW).

The chemistry program is co-ordinated by D. Guzonas (AECL).

3. Activities at the University of New Brunswick

D. Lister

Heat exchanger fouling; examining the effects of surfactants on magnetite deposition during boiling heat transfer (collaboration with AECL). Preliminary studies developed an accurate way of measuring local deposit thicknesses ex-situ.

Flow-accelerated corrosion; predicting the characteristics of scallops (the sculpting of surfaces undergoing FAC). Correlating the pattern of FAC recorded in many laboratory experiments at different conditions of flow, pH, etc. will lead to greater understanding of the FAC phenomenon in general.

Modelling reactor primary circuit contamination. Inserting FAC mechanisms and in-core effects into models for material transport will lead to predictions of radiation fields.

Sampling high-temperature water systems; modelling hold-up of corrosion products in coolers and introducing precipitation kinetics provides information relevant to the IAPWS technical guidance document.

Characterising the effects of film-forming amines on FAC in two-phase flow. Scoping studies in single-phase flow are complete and similar experiments under two-phase flow at 200C are imminent.

W. Cook

Active involvement in the Generation IV Technologies Program for development of the SCWR. The major focus is corrosion-product transport and deposition in the core of a SCWR where both experimental techniques and modeling are employed to elucidate material corrosion and the deposition kinetics of the "fall-out" from solution that occurs upon traversing the critical point.

Electrowinning of metals from solutions is an additional industrial project of note. Initial work (modelling and some experimental) has been undertaken on zinc, indium and manganese production. Optimization of modelling involves use of the PCAS thermodynamic models.

4. Activities at the University of Guelph (Prof. Peter Tremaine)

CURRENT PROJECTS

CANDU Nuclear Reactor Chemistry: D_2O Isotope Effects on Acid-base Ionization and Metal Hydrolysis (UNENE/NSREC CRD Grant)

Metals and Fission Products in Sub-critical and Supercritical Water (NRCan/AECL/ NSERC CRD Grants):

Boric Acid Speciation and Phase Behaviour up to 350 ^{o}C at 25 MPa : (EPRI)

Phase Separating Amines for Carbon Capture (NSERC Iinternational Strategic Grant with University Blaise Pascal, France)

5. Activities at the University of British Columbia (Prof. Rich Pawlowicz)

Activities related to the subcommittee on seawater (SCSW):

Proposal of the Joint Committee on the Properties of Seawater to SCOR and IAPSO, who accepted (so it is now the IAPWS/SCOR/IAPSO Joint Committee on the Properties of Seawater (JCS)

Development of membership of JCS, became chair. As JCS chair, organization of workshops at ICPW16 to explore IAPWS/BIPM collaboration.

With the assistance of Chuning Wang, a new graduate student from China, five Chinese-language scientific articles on "Chinese Standard Seawater" (the oceanographic conductivity reference material used in China about which little is known in the west) were translated. The documents were circulated to JCS members for comments from the membership, especially Industry representatives.

6. Activities Planned to next ICPWS (2017/18)

The CNC discussed potential activities over the next 4 - 5 year period and mostly intend to carry on work that is currently ongoing, as described above. The supercritical water-cooled reactor project is a focus for much of the current research activities of the CNC. This university-government-industry program focused on fundamental research will conclude Phase II in 2016 but it is currently planned to have more focused research beginning in Phase III.

Each of the CNC members and IAPWS-involved researchers in Canada are involved in industry-sponsored research with organizations such as EPRI and the Candu Owners Group pertinent to topics of interest to IAPWS.

The CNC identified that the reformulation of the properties of heavy water is of great interest to Canada and will likely provide contacts with the CANDU community to support the work.

7. Select List of Publications

1. Water Chemistry in a Supercritical-Water-Cooled Pressure-Tube Reactor, D. Guzonas, F. Brosseau, P. Tremaine, J. Meesungnoen, J.-P. Jay-Gerin, Nuclear Technol. 179, 205-219 (2012).

2. Ionization Constants and Thermal Stabilities of Uracil and Adenine under Hydrothermal Conditions as Measured by in situ UV-Visible Spectroscopy, E. Balodis, L.N. Trevani, and P.R. Tremaine, Geochim. Cosmochim. Acta 93, 182-204 (2012).

3. Limiting Conductivities and Ion Association Constants of Aqueous NaCl under Hydrothermal Conditions: Experimental Data and Correlations. G. H. Zimmerman, H. Arcis, and P. R. Tremaine. J. Chem. Eng. Data 57, 2415-2429 (2012).

4. Limiting Conductivities and Ion Association in Aqueous NaCF3SO3 and Sr(CF3SO3)2 from 298 to 623 K at 20 MPa. Is Triflate a Non-Complexing Anion in High Temp-erature Water? G. H. Zimmerman, H. Arcis, and P. R. Tremaine. J. Chem. Eng. 57, 3180–3197 (2012).

5. A Raman and Ab Initio Investigation of Aqueous Cu(I) Chloride Complexes from 25 to 80 oC. L.M.S.G.A. Applegarth, C.R. Corbeil, D.J.W. Mercer, C.C. Pye and P. R. Tremaine, J. Phys. Chem. B (Submitted).

6. Solution Calorimetry Under Hydrothermal Conditions, P.R. Tremaine and H.Arcis, . Rev. Mineralogy Geochemistry. Vol 76, Chapt. 7 (Geochem Soc. & Mineral. Soc. Amer., 2013).

7. Ab Initio and Raman Investigation of Co(II) Complexes C. C. Pye, D. C. M. Whynot, L. Applegarth, J. Cox, P. Tremaine, Proc. 3rd China-Canada Joint Workshop on Supercritical Water-cooled Reactors, (CCSC 2012) (Xi'an, Shaanxi, China, April 18-20, 2012).

8. Ab initio and Raman Investigation of Ni(II) Complexes C. C. Pye, L. Cheng, J. P. Ferguson, K. Bissonette, L. Applegarth, J. Cox, P. R. Tremaine, Proc. 3rd China-Canada Joint Workshop on Supercritical Water-cooled Reactors, (CCSC 2012) (Xi'an, Shaanxi, China, April 18-20, 2012).

9. Non-Complexing Anions for Physico-Chemical Studies by Raman Spectroscopy under Hydrothermal Conditions L.M.S.G.A. Applegarth, C. Alcorn, K. Bissonnette, J. Noel and P.R. Tremaine, Proc. 16th Int. Conf. Properties of Water and Steam (IAPWS & Inst. Mech. Eng.; Greenwich, U.K., Sept. 1 - 5, 2013)

10. Ion Pair Formation Constants and Transport Properties for Aqueous Strontium Complexes up to 350°C at 20 MPa by Flow AC Conductance, H. Arcis, G.H. Zimmerman‡ and P.R. Tremaine†,*Proc. 16th Int. Conf. Properties of Water and Steam (IAPWS & Inst. Mech. Eng.; Greenwich, U.K., Sept. 1 - 5, 2013).

11. Pawlowicz, R. (2013) Key Physical Variables in the Ocean: Temperature, Salinity, and Density. Nature Education Knowledge 4(4):13 http://www.nature.com/scitable/knowledge/library/key-physical-variables-in-the-ocean-temperature-102805293

12. Pawlowicz, R., and R. Feistel, Limnological Applications of the Thermodynamic Equation of Seawater 2010 (TEOS-10), Limnology and Oceanography:Methods, 10:853-867, (2012)

13. McDougall, T. J., D. R. Jackett, F. J. Millero, R. Pawlowicz and P. M. Barker, 2012: A global algorithm for estimating Absolute Salinity. Ocean Science, 8, 1117-1128.

14. Ishida, K. and Lister, D.H. (2012). "In-Situ Measurement of Corrosion of Type 316 Stainless Steel in 280ºC Pure Water via the Electrical Resistance of a Thin Wire". J. Nucl. Sci. Tech., 49 (11), November.

15. Uchida, S., Naitoh, M., Okada, H., Ohira, T., Koshizuka, S. and Lister, D.H. (2012). "Verification and Validation of Evaluation Procedures for Local Wall Thinning due to Flow Accelerated Corrosion and Liquid Droplet Impingement". Nuclear Technology, 178, 280-297.

16. Uchida, S., Naitoh, M., Okada, H., Suzuki, H., Koikari, S., Koshizuka, S. and Lister, D.H. (2012). "Determination Procedures of High Risk Zones for Local Wall Thinning due to Flow Accelerated Corrosion". Nuclear Technology, 180, 65-77.

17. Lister, D.H. (2012). "Corrosion Mitigation in Nuclear Reactor Systems". Chapter in Nuclear Corrosion Science and Engineering, Ed. Damien Feron, Woodhead Publishing Ltd.

18. Phupongskorn, T., Rirksomboon, T., Lister, D.H. and Steward, F.R. (2012). "Determination of Impinging Jet Correlation and Dissolution of Materials". Chem. Eng. Trans., 29,

19. Lister, D.H. and Khumsa-Ang, K. (2013). "Oxide Particle Deposition under Low-Temperature Cooling Water Conditions: Experiments under Subcooled Boiling at High pH". Heat Trans. Eng., Vol. 34, Issues 8-9 (April-May).

20. Lertsurasakda, C., Srisukvatananan, P., Liu, L., Lister, D. and Mathews, J. (2013). "The Effects of Amines on Flow-Accelerated Corrosion in Steam-Water Systems". Power Plant Chem., 15, (3), 181-189.

21. Suzuki, H., Uchida, S., Naitoh, M., Okada, H., Koikara, S., Hasegawa, K., Kojima, F., Koshizuka, S. and Lister, D.H. (2013). "Risk Evaluation of Flow-Accelerated Corrosion Based on One-Dimensional FAC Code". Nuclear Technology, 183, 194-209.

22. Suzuki, H., Uchida, S., Naitoh, M., Okada, H., Koikara, S., Nagaya, Y., Nakamura, A., Koshizuka, S. and Lister, D.H. (2013). "Verification and Validation of One-Dimensional Flow Accelerated Corrosion Evaluation Code". Nuclear Technology, 183, 62-74.

23. Mohajery, K., de Pierrefeu, L.D. and Lister, D.H. (2012). "The Dissolution Rate Constant of Magnetite in Water at Different Temperatures and pH Conditions". Proc. NPC 2012; Intern. Conf. Water Chem. Nucl. Reactor Systems. Paris, France. Sept. 23-27.

24. Lertsurasakda, C., Srisukvatananan, P., Lihui, L., Lister, D. and Mathews, J. (2013). "The Effect of Amines on FAC in Steam-Water Systems". Proc. 2013 Intern. Conf. on FAC in Fossil Systems, Arlington, Washington D.C., March 26th-28th.

25. Kippers, N., Phromwong, P., Mathews, J. and Lister, D.H. (2013). "Modelling FAC Under Conditions of Accentuated Turbulence in Feedwater". Proc. 3rd Intern. Conf. on FAC", EdF – DTG. Avignon, France, May 21st-24th.

26. Gasnier, C. and Lister, D. (2013). "The Effects of Chemical Additives on Magnetite Deposition in Boiling Heat Transfer". Proc. Intern. Conf. on Heat Exchanger Fouling and Cleaning, Budapest, Hungary, June 9th-14th.

27. Uchida, S., Naitoh, M., Okada, H., Suzuki, H., Koshizuka, H. and Lister, D.H. (2013). "Contribution of Probabilistic Risk Evaluation of Flow-Accelerated Corrosion to System Safety Analysis of Aging NPPs". Proc.16th Intern. Conf. Props. Water and Steam, Greenwich, London, UK. Sept. 1st-6th.

28. Addison, D., Lister, D. and Thomsen, K. (2013). "Monitoring and Analysing Total Iron and Copper in Fossil and Combined Cycle Plants – Technical Guidance Document". Proc.16th Intern. Conf. Props. Water and Steam, Greenwich, London, UK. Sept. 1st-6th.

29. Srisukvatananan, P., Lertsurasakda, C., Lister, D. and Mathews, J. (2013). "Sampling Amines from Flowing Steam-Water Mixtures". Proc.16th Intern. Conf. Props. Water and Steam, Greenwich, London, UK. Sept. 1st-6th.

30. Lister, D., Srisukvatananan, P. and Uchida, S. (2013). "Sampling Nuclear Reactor Coolant Systems". Proc.16th Intern. Conf. Props. Water and Steam, Greenwich, London, UK. Sept. 1st-6th.

31. Guzonas, D.A. and Cook, W.G., Cycle chemistry and its effect on materials in a supercritical water-cooled reactor: A synthesis of current understanding, Corrosion Science vol. 65, pp. 48–66, December 2012.

32. Raoul, B. and Cook, W., *Studying Stress-Corrosion Cracking (SCC) in Supercritical Water Environments using Spring-Loaded C-Ring Samples*, The Sixth International Symposium on Supercritical Water Reactors (ISSCWR 6), Guangdong, China, March 2013.

33. Guzonas, D., Bissonette, K., Deschenes, L., Dole, H. and Cook, W., *Mechanistic Aspects of Corrosion in a Supercritical Water-cooled Reactor,* The Sixth International Symposium on Supercritical Water Reactors (ISSCWR 6), Guangdong, China, March 2013.

34. Jiao, Y., Mabhoubi, S., Kish, J., Cook, W., Zheng, W., Guzonas, D., *Influence of Thermal Ageing on the Corrosion Resistance of Austenitic Fe-Cr-Ni Alloys in SCW*, The Sixth International Symposium on Supercritical Water Reactors (ISSCWR 6), Guangdong, China, March 2013.

35. Cook, W. and Olive, R., *Corrosion Product Transport and Deposition in a Supercritical Water-Cooled Reactor,* Accepted to the ICPSW16, Greenwich, UK, September 2013.

36. Cook, W. and Olive, R., *Predicting Corrosion Product Solubility in Supercritical Water using Revisited HKF-model Parameters and Thermodynamic Modelling,* Accepted to the ICPSW16, Greenwich, UK, September 2013.