THE INTERNATIONAL ASSOCIATION FOR THE PROPERTIES OF WATER AND STEAM

MEMBERS
Britain and Ireland
Canada
Czech Republic
Germany
Japan
New Zealand
Russia
Scandinavia (Denmark, Finland, Norway, Sweden)
United States of America

ASSOCIATE MEMBERS
Argentina and Brazil
Australia
Egypt
France
Greece
Switzerland

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Minutes of the Meetings

of the

Executive Committee

of the

International Association for the Properties of

Water and Steam

Dresden, Germany
11th – 16th September 2016

Prepared by: Barry Dooley

IAPWS

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Minutes of the Meetings
of the
Executive Committee
of the
International Association for the Properties of Water and Steam
held in
Dresden, Germany
11th – 16th September 2016

Plenary Session. Monday, 12th September 2016. 8:30am

The President of IAPWS, Professor Hans-Joachim Kretzschmar, welcomed the Executive Committee (EC) and other IAPWS members to Dresden for the Executive Committee and Working Group (WG) Meetings of IAPWS. The President informed the EC that President Guzonas had stepped down from the IAPWS presidency in March 2016 and that, as Vice President, he had taken over the duties. The President then officially opened the 2016 EC Meetings by introducing the National Delegates. Each of the Member countries of IAPWS was in attendance as well as Associate Members, Australia, New Zealand and Switzerland. In total there were 77 people assembled for the EC meeting.

The President, as head of the local organizing committee, indicated that the EC meetings had been arranged by Zittau/Görlitz University of Applied Sciences in cooperation with the Ruhr University Bochum, Dresden University of Technology and VDI - The Society of German Engineers. He also wanted to thank the Exhibitors and Co-sponsors: Swan Analytical Instruments, Siemens Power and Gas, Steag Energy Services, VPC Group and DREWAG Stadtwerke.

1. Adoption of Agenda

Provisional agendas had been posted on the IAPWS Website for all IAPWS members by the Executive Secretary. There were a few changes and the final agenda was then approved by the Heads of all National Delegations, and forms Attachment 1 of these minutes.

2. IAPWS Business and Appointment of Committees

2.1 Releases, Advisory Notes, ICRNs and Technical Guidance Documents

The Executive Secretary indicated that four documents had been circulated to the National Committees during the year since the Stockholm meeting for final approval or review prior to the current EC Meeting. The Executive Secretary reminded the EC of these documents:

- *IAPWS Certified Research Need (ICRN). Thermophysical Properties of Supercooled Water.* The ICRN 30 had been approved by TPWS/SCSW in Stockholm and was circulated for approval by the National Committees on 7th July 2015. No comments or objections were received. Thus the document was approved on 7th November 2015.

- IAPWS Guideline. *Guideline of the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL)*
  In Stockholm the EC approved sending the Guideline for Postal Ballot after editorial changes. The Guideline was distributed to National Committees on 17th

December 2015. No comments or objections were received. Thus the document was approved on 18th March 2016.

- *Technical Guidance Document – HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemically Clean.* Distributed on 16th March 2016 for postal ballot. A number of comments were received from the National Committees. These were all addressed by the PCC Task Group. The TGD was recirculated to the National Committees and no further objections or comments were received by 30th June 2016. The document will be reviewed finally by the PCC working group during the week prior to approval at the Friday EC.

- *Technical Guidance Document – Application of Film Forming Amines in Fossil, Combined Cycle, and Biomass Plants.* Distributed on 28th May 2016 for postal ballot. A number of comments were received from the National Committees. These were all addressed by the PCC Task Group. The TGD was recirculated to the National Committees and no further objections or comments were received by 31st August 2016. The document will be reviewed finally by the PCC working group during the week prior to approval at the Friday EC.

2.2 Press Release.

The President asked Cook to chair the development of the Highlights/Press Release on the IAPWS proceedings during the week. It was also suggested that Feistel and Herrmann assist in this development. The Clerks of Minutes from each WG were asked to provide input. The Press Release is discussed in Minute 18.1 and is Attachment 9.

2.3 Evaluation Committee on International Collaboration.

The President indicated that no proposals had been received by the Executive Secretary prior to the meeting, and that any suggestions from WGs should be given to the Executive Secretary by the end of day. The President then reminded the EC that the Committee to review any proposals received would consist of the WG Chairmen, with the President and Executive Secretary as ex. officio members. A chairman would be chosen by the Committee. (See Minute15 for further discussion on International Collaborations).

2.4 IAPWS Awards Committees

2.4.1 Helmholtz Award Committee

The President indicated that there was a Helmholtz Awardee this year. The Executive Secretary then reminded the EC that the Helmholtz Committee for the 2017 award would consist of a member from Japan, Russia, SIAPWS, USA and BIAPWS. Japan will provide the committee chairman. The President asked Japan delegate Nakahara to organize the committee and to report back to the EC on Friday with the names of the members of this committee (see Minute 16.1).

2.4.2 Honorary Fellow Award Committee

The President requested that Friend (Chairman) and Petrova form the Committee for 2017. The President would be ex. Officio.

2.4.3 Gibbs Award

The President reminded the EC that the Gibbs Award is awarded every five years at each ICPWS. He then requested that the heads of National Committees, Working Groups and Sub-committees provide a nomination for the 2018 Gibbs Award by 31st May 2017 to the Executive Secretary. A selection committee will be formed at the 2017 EC Meetings in Kyoto, Japan and the Gibbs Awardee will be named at that time.

2.5 Numbering of IAPWS Documents (Stockholm 2015 IAPWS Minute 17.2)

The President requested the chair of the Committee, Harvey, to address this item. Members of the committee had been the other members of the Editorial Committee, Cook and Cooper. Harvey reported that there had been the following basic principles in developing the numbering system:

- Identifiers should be unique and concise.
- There should be clear distinctions for different document types.
- Identifier can show revisions, but retain original identifier in some way.
- Retain existing numbering schemes for Advisory Notes and ICRNs.
- It is desirable for "IAPWS" to be part of the identifier

Based on these the committee recommends the following:
IAPWS TYPEnn-yy(revyear) where

- TYPE is R (Release), SR (Suppl. Rel.), G (Guideline), AN (Adv. Note), TGD
- nn = numerical sequence of first adoption
- yy = 2-digit year of first adoption
- revyear = 4-digit year of most recent revision or editorial change (omitted if no revision yet)

Some examples were provided for the EC and the following notes of clarification were also dicusseed:

- In the unlikely event of multiple revisions for a document in a year, the second revyear would be (2016b)
- The new scheme would be retroactively applied to existing documents (but not obsolete documents).
- The existing ICRN numbering would be kept.
- It will be recommended that the identifier will be used in addition to the full title when citing IAPWS documents. (example: *IAPWS R6-95(2014): Revised Release on the IAPWS Formulation 1995 for* …)
- The identifier will be placed on the cover page (and webpages where documents linked) at the top right of cover page.

The President asked the EC if there were any comments of suggestions and then asked the EC for approval.

The EC voted unanimously to adopt the new numbering scheme for IAPWS Documents.

2.6 17th ICPWS. Formation of International Program Committee (IPC)

The President requested the Chair of the Organizing Committee for the 17th ICPWS, Hruby, to introduce this topic. Hruby first reminded the EC of the 2nd - 7th September 2018 dates for the ICPWS in Prague, Czech Republic. He then briefed the EC on location, local organizing committee and the sponsors. The International Program Committee (IPC) needed to be formed and to meet during this IAPWS EC Week. This committee consist of the Chairs of the Working Groups, IAPWS President and Executive Secretary, and Cooper as the Chair of the 16th ICPWS. A further report on the 17th ICPWS is found in Minute 14.2.

2.7 Overview of OPAL Website for IAPWS Documents and Presentations

The President reminded the EC that there was a Users Guide for the Opal Website in the conference package. This is a password protected site for use by the IAPWS Working Groups.

2.8 Other Business Requiring Extensive Discusssions

No other business was raised by the EC.

3. EC Mandate to Working Groups and Membership

The President then provided the following mandates to the WG Chairmen for action during the week.

3.1 Releases, Guidelines and Certified Research Needs.

The Executive Secretary indicated that two ICRNs needed attention during the week: #22 on steam chemistry in the phase transition zone (PTZ) and #29 on uncertainties in coolant sampling for low concentration metals.

3.2 Working Group Directions.

The President emphasized that each WG Chairmen should only report to the EC on Friday about those activities that need approval or discussion by the EC.

4. Preview by the Working Group (WG) Chairmen of the Week's Activities

President Kretzschmar requested each WG Chairman to review briefly the main topics which would be covered in their WGs during the week. The details of the WG meetings are covered in detail in Minutes 7 to 11 (Attachments 4 to 8).

The President then introduced Professor Friedrich Albrecht, Rector of Zittau/Görlitz University of Applied Sciences to provide a welcoming address to the IAPWS EC.

Following this address, the President closed the opening session of the EC at 9:40 am.

Activities During the Week in Dresden

The first day activities of the WGs and Executive Committee were followed by the separate and joint WG meetings on Monday, Tuesday and Thursday.

The full IAPWS program for the week is shown in Attachment 2.

The IAPWS Symposium was held on Wednesday, 14th September 2016 and the Symposium Program is shown in Attachment 3.

Executive Committee Meeting. Friday, 16th September 2016

President Kretzschmar opened the continuation of the EC Meeting at 9:00 am. Each of the Member countries of IAPWS was in attendance as well as Associate Members Australia, New Zealand and Switzerland. In total there were 25 people assembled for the EC meeting. Kretzschmar first asked the EC if there were any additional items that should be added to the Agenda. None were suggested. The Executive Secretary showed the latest Agenda with additional items relating from the Monday EC Meeting.

5. Acceptance of Minutes of Previous Meeting

President Kretzschmar asked for comments and changes to the minutes of the EC meeting held in Stockholm, Sweden in 2015. No changes were noted, thus the 2015 Minutes were accepted.

6. President's Report

President Kretzschmar indicated that the possible new associate memberships of China, Italy and Egypt are very important for IAPWS. He indicated that the IRS working group must survive and that members from industry are very important for IAPWS. Traditionally, the requirements for the development of standards come from industry. He was hopeful that IRS can be strengthened by PCC members. The Technical Guidance Documents of PCC are penetrating into the power plant chemistry and creating worldwide interest. These are putting IAPWS in a leadership position. The President thought that IAPWS should find new working areas as well as the historical areas of power plant industry, energy, refrigeration, air-conditioning, supply and disposal technology, oceanography, atmospheric research, geothermal technology and power plant chemistry. He recognized that members with longterm experience in IAPWS are very important to help find the right future directions and decisions. Finally, he indicated that the working groups and national committees should try to make IAPWS better recognized around the world. He requested that a task group is formed of the chairs of the working groups and national committees to address this important item, and that each should provide proposals/suggestions within the next month to the Executive Secretary.

7. Report and Recommendations of the Thermophysical Properties of Water and Steam (TPWS) Working Group

TPWS Chairman Harvey opened this item by indicating that he would report on the activities relating to TPWS although a number of joint meetings with IRS and SCSW had taken place during the week. Full Minutes and the Agenda for TPWS can be found in Attachment 4.

7.1 The International Collaborative Project on "*Toward an IAPWS Guideline on the Thermodynamic Properties of Supercooled Heavy Water*" was approved in 2015 for a young Czech scientist to spend some time at the University of Maryland. The original allocation was £17,490 GBP, which is now inadequate due to the exchange rate. TPWS requested that the amount allocated to this project be increased by an amount (to be calculated by the Executive Secretary) to make the total number of US dollars available now equal to the number of US dollars that the original allocation would have bought at the time of the Stockholm meeting.

The EC approved this Recommendation Unanimously.

7.2 Harvey reported on a minor revision of the IAPWS-95 release on thermodynamic properties of water for general and scientific use. This involved refined uncertainty estimates for isobaric heat capacity and changes in the language about extrapolation into metastable regions to account for new experimental data. The actual formulation is unchanged. TPWS had approved the revision, and the Chairman requests the EC to authorize a Postal Ballot after Editorial Committee review.

The EC approved the Process Unanimously.

7.3 The TPWS Chair then provided five informational items for the EC.

i) A Task Group was formed to consider developing an IAPWS document based on recent work on an explicit approximation for the enhancement factor of water in humid air (and humid gases more generally). The Task Group consists of Hellmuth (Chair), Hrubý, Feistel, Harvey, Cooper, and Kretzschmar.
ii) A Task Group continues to work on a new equation of state (EOS) for heavy water. It was decided that the equation would be finalized based on data available by the end of 2016, with a deadline of 31st May 2017 for producing the EOS and a draft Release, and a deadline of 31st July 2017 for completion of the work of the Evaluation Task Group. Kretzschmar was appointed Chair of the Evaluation Task Group.
iii) A Task Group continues to work on a possible revision of the IAPWS formulations for melting curves of ice. It is hoped that the revision will be ready for IAPWS adoption in 2017.
iv) A Task Group continues to work toward a new formulation for the surface tension of water. The database is expected to be finalized soon, and a proposed new equation may be ready for consideration in 2017.
v) An update to the Guideline on the Use of Fundamental Physical Constants and Basic Constants of Water (reflecting a new international adjustment of the fundamental physical constants) was approved.

7.4 Gibbs Award.

Chairman Harvey indicated that Friend would be the TPWS member of the Gibbs Award Committee to be assembled at the 2017 EC meetings in Kyoto.

7.5 TPWS Membership. Chairman Harvey first informed the EC that long standing member Phil Hill from Canada had passed away during the last year. He then requested EC approval for three new TPWS WG members who had been approved by the WG:

- Dr. Frédéric Caupin (University of Lyon, France)
- Dr. Andreas Jäger (TU-Dresden, Germany)
- Dr. Simona Lago (INRIM, Italy)

The EC approved these Membership Additions Unanimously.

8. Report and Recommendations of the Industrial Requirements and Solutions (IRS) Working Group

IRS Chairman Weber indicated that many of the activities of IRS during the week had been reported in the TPWS report. Minutes for IRS and the Agenda can be found in Attachment 5. He covered the following items with the EC.

8.1 Task Group on Industrial Advisory Note (AN).

There had been no developments since the last meeting, but the requirement for the AN needs to be clarified within IRS and also with PCC. If there is a requirement, then progress will be made before the 2017 meeting with a draft being circulated.

8.2 Editorial Changes to IAPWS Documents.

Weber indicated that this was applicable to two documents:

- Revised Supplementary Release on Backward Equations for Specific Volume as a Function of Pressure and Temperature v(p,T) for Region 3 of the IAPWS Industrial Formulation 1997.
- Advisory Note 5: Industrial Calculation of the Thermodynamic Properties of Seawater.

The Editorial changes had been presented and discussed. The Working Groups IRS, TPWS and SCSW recommend to adopt these changed documents.

The EC approved these Changes Unanimously.

8.3 The Future of the IRS WG.

Chairman Weber indicated that the following few technical topics had been identified, but either the demand in the industry does not exist or they were not in IRS scope:

- Transport properties in wet steam
- Wetness measurements

- Frost formation
- Freezing phenomena
- Slurry ice properties

Weber then informed the EC that a Task Group would be formed on wet steam transport properties which would categorize topics (within / outside current IAPWS scope, etc.), communicate and discuss within IRS, and identify potential experts to be involved for these topics. These are potential topics for 17th ICPWS in Prague.

8.4 Gibbs Award.

Chairman Weber indicated that he would be the IRS member of the Gibbs Award Committee to be assembled at the 2017 EC meetings in Kyoto.

8.5 Membership and Officers of IRS.

The IRS Chairman requested EC approval for one new IRS WG member who had been approved by the WG:

- Dr. Tobias Löw (STEAG Energy Services GmbH, Germany)

The EC approved this Membership Addition Unanimously.

Weber then informed the EC that he would be retiring as Chairman of IRS and that the WG requested EC approval for the new officers of the WG:

- Chair: Nobuo Okita, Toshiba, Japan
- Vice-Chair: Adam Novy, Doosan Skoda Power, Czech Republic

The EC approved these New IRS Officers Unanimously.

The President then requested that the EC shows thanks to Weber for the excellent leadership of the IRS WG.

9. Report and Recommendations of the Sub-Committee on Seawater (SCSW)

SCSW Chairman Pawlowicz reported on the following items. Minutes for SCSW and the Agenda can be found in Attachment 6.

9.1 Information for EC.

- A Task Group on humid air fugacity and enhancement factor (Hellmuth, Feistel, Harvey, Hruby, and Cooper) was established to formulate the requirements and content of a possible IAPWS guideline as a further contribution to realise the roadmap fixed at the ICPWS 2013 workshop on humidity and as a contribution to further cooperation of IAPWS with BIPM.
- For the extension of the range of formulation for the thermodynamic properties of seawater (Feistel et al.) the TG was requested to continue their work.

- Reports on the Joint Committee of Seawater (JCS) (downloads of TEOS-10) have increased slightly this year, and the IAPWS/BIPM Cooperation on the long-awaited Metrologia paper is now published and has been incredibly successful (most "read" from that journal).
- The SCSW Chair had received a request from the Chair of ISO TG28 SC 2 WG 4 for assistance on the use of water in the petroleum industry. A SCSW task group was formed (Pawlowicz, Feistel, Anderko, Harvey, and Hellmuth) to give a detailed reply, formulate items of common interest and to ask for the possibilities of financial support. A representative of WG 2 will be invited to the next IAPWS meeting for further discussion of specific research targets.
- Proposed guideline for the electrical conductivity of seawater. A SCSW Task Group was formed (Pawlowicz, Feistel, Seitz, and McDougall).
- The Task Group for the Supplementary Release for a Simplified Density Equation was disbanded.
- The next BIPM-CCT meeting (planned for spring 2016) was postponed to spring 2017. The SCSW Chair indicated to the EC that the support for sending a SCSW representative to the 2016 meeting will be used for the 2017 meeting.

9.2 EMPIR Proposal.

The Chairman of SCSW proposed that IAPWS support an upcoming EMPIR proposal (approximate budget €2M) coordinated by Seitz (a SCSW and JCS member) by writing a letter signed by IAPWS President. The proposed work will support the tasks of JCS.

The EC approved this Process Unanimously.

9.3 Advisory Note.

The Chairman next indicated that an Advisory Note will be written on clarifying the IAPWS documents which contribute to TEOS-10. This will require editorial review before being sent for Postal Ballot.

The EC approved this Process Unanimously.

9.4 Gibbs Award.

Chairman Pawlowicz indicated that he would be the SCSW member of the Gibbs Award Committee to be assembled at the 2017 EC meetings in Kyoto.

9.5 Membership.

Pawlowicz then indicated that Spitzer had retired and should be removed from the SCSW membership list.

10. Report and Recommendations of Physical Chemistry of Aqueous Systems Working Group (PCAS)

Chairman Anderko provided the PCAS Report to the EC. Full Minutes can be found in Attachment 7. He covered the following informational items with the EC:

10.1 Guidelines.

Anderko reported that a guideline on *Self-diffusion in High Temperature and Supercritical Water over Wide Density Ranges* was under development by Nakahara and Yoshida. Experimental papers have been already published and work on the guideline has been initiated. A draft will be prepared for the 2017 IAPWS meeting and an evaluation committee will be appointed.

The Chairman also reported that another guideline on *Solubility of H_2S in Water and Aqueous Solutions of NaCl and $CaCl_2$* is also under development by Majer. Experimental and modeling papers have been already published and work on the guideline will be initiated. An evaluation committee will be appointed.

Two other guidelines are also possible on the *Dissociation and Vapor-liquid Distribution of Amines* (Bellows) and *Thermodynamics of Hydration of Gases and Organic Solutes* (Sedlbauer and Majer).

10.2 Gibbs Award.

PCAS Chairman Anderko indicated that he would be the PCAS member of the Gibbs Award Committee to be assembled at the 2017 EC meetings in Kyoto.

11. Report and Recommendations of Power Cycle Chemistry Working Group (PCC)

Chairman Rziha provided the PCC Report to the EC. Full Minutes can be found in Attachment 8. He covered the following items with the EC:

11.1 Technical Guidance Documents (TGD).

Chairman Rziha requested EC approval for two TGDs:

- *The Application of Film Forming Amines in Fossil, Combined Cycle, and Biomass Power Plants.*
- *HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemical Clean*.

Both documents had received a final review by the PCC Working Group during the week following extensive review by National Committees and the Editorial Committee twice.

The EC approved these TGD Unanimously.

11.2 Technical Guidance Documents (TGD) under Development.

Chairman Rziha informed the EC that the TGD Task Group (Chair: Dooley) had intiated the following activities during the week.

- *Monitoring Corrosion Products in Flexible (cycling and two-shifting) Plants*. The Task Group (Addison, Cook, McCann and Thomsen) will develop a White Paper for the 2017 Meeting.
- *Ensuring the Integrity and Reliability of Demineralised Makeup Water Supply to the Unit Cycle*. The Task Group (Joy, Chair) will develop the final TGD by the 2017 Meeting
- *Application of Film Forming Amines in Nuclear Plants*. The Task Group (Cook, Chair) will develop the TGD by the 2017 Meeting.
- *Aspects of Geothermal Steam Chemistry*. The Task Group (Addison, Chair, plus representatives from Geothermal Countries) will develop a White Paper for the 2017 Meeting. This will be used to determine if a TGD can be developed.
- *Air In-Leakage in Steam Water Cycles*. The Task Group (Carvalho, Chair, Dooley, Rziha and Thomsen) will develop a White Paper for the 2017 Meeting which can be easily transitioned into a TGD. Comment was received from BIAPWS delegate, Cooper, that performance effects of air in-leakage could also be included as well as the chemistry aspects.

11.3 IAPWS Certified Research Needs (ICRN).

Chairman Rziha provided the EC with the following information for approval.

- ICRN 22 on *Steam Chemistry in the Phase Transition Zone (PTZ)*. This document has been finalized with a new expiry date of September 2018. The document will receive a light review by the Editorial Committee and then be sent for Postal Ballot.

- ICRN 29 on *Uncertainties in Coolant Sampling for Low Concentration Metals* (Fe, Cu, Co, etc). This document has been finalized with a new expiry date of September 2020. The document will receive a light review by the Editorial Committee and then be sent for Postal Ballot.

The EC approved these ICRN Actions Unanimously.

11.4 PCC Membership and Officers.

Chairman Rziha requested that the following new members be approved:

- Sho Shinotsuka (Mitsubishi Hitachi Power Systems, Japan)
- Dr. Yoichi Wada (Hitachi, Japan)
- Luis Carvalho (ChemTreat, Canada)
- Moataz Khalifa (PGESCo, Egypt)
- Dr. Andreas Wecker (VGB Powertech, Germany)
- Monika Nielsen (Dong Energy, Denmark)

- Utku Keren Gülcek (EnerjiSA, Turkey)
- Mike Sparrey (ABB, UK)

The EC approved these Membership Additions Unanimously.

Chairman Rziha then informed the EC that the PCC WG had requested him to remain as Chairman for an additional few years.

The EC approved this Extension of Chairmanship Unanimously.

12. Editorial Committee Report

Editorial Committee Chairman Harvey reported that in the preceding year, the Editorial Committee had reviewed the documents delineated in Minute 2.1.

Harvey then indicated that a large number of documents will need editorial review over the next year and requested early notification.

13. Membership and Associates

13.1 Member Dues.

The Executive Secretary indicated that all IAPWS Members except BIAPWS had paid their 2016 dues. The BIAPWS Delegate, Sparrey, indicated that there had been a time delay in changing over BIAPWS officers in 2016 and that the IAPWS Dues would be paid soon.

13.2 Application for IAWPS Membership.

The Executive Secretary informed the EC that New Zealand wished to apply for membership and asked the Chair of the New Zealand National Committee, Addison, to provide the details.

Addison indicated that the TGDs are used extensively across New Zealand and that there was a growing geothermal interest in the IAPWS Releases and Guidelines. The National Committee had decided to change from an individual subscription model to industry sponsored. This had delayed the funding but commitments for full funding have been given from multiple sources across New Zealand. Bank accounts and the financial structure are also in place. Addison provided the names of the NZAPWS committee. New Zealand is ready for full membership in IAPWS and Addison requested approval from the EC.

The EC approved the Application for IAPWS Membership of NZAPWS Enthusiastically and Unanimously.

13.3 Reports on Associate Members

Application of Egypt as an IAPWS Associate Member.

The Executive Secretary informed the EC that Egypt had applied for IAPWS Associate membership and asked the Chair of the Egypt National Committee, Khalifa, to provide the details.

Khalifa indicated that he and his company PGESCo (Power Generation Engineering and Services Co.) have been taking the lead to work representing IAPWS in Egypt. There is currently about 40,000 MW of generating capacity in Egypt which will expand to over 60,000 MW by 2020. This power generation needs rugged guidelines; the cycle chemistry and properties of water and steam are vital. The current interests are to support the power and desalination industries. As the Egypt IAPWS National Committee develops Khalifa will try to include all the entities involved in the power generation industry including electricity holding companies, utilities, independent power producers, and local EPC contractors. Universities and research institutes will also be contacted. Khalifa is working towards having a first meeting in April 2017. He then requested the EC to approve the application to become an IAPWS Associate Member, and indicated that he will report back to the EC on progress at the 2017 meeting in Kyoto.

The EC approved the Application of Egypt to Become an IAPWS Associate Member Unanimously.

Status Report on IAPWS Associate Member, Australia. Delegate McInnes standing in for Chairman Joy provided a short presentation. The Australian National Committee (AUSAPWS) is planning to apply for full IAPWS Membership in 2017 in Kyoto. AUSAPWS has continued to focus on the Power Cycle Chemistry area but is also developing a wider focus in seawater, carbon sequestration and thermodynamics. McInnes indicated that AUSAPWS has developed By-Laws and is finalizing funding arrangements with API (Australian Power Institute), other companies and individual memberships and sponsorships to complete AUSAPWS funding.

Status Report on IAPWS Associate Member, Switzerland. Chairman Lendi indicated that the Swiss National Committee (SCPWS) will be hosting an international conference on FFA / FFAP in Lucerne in April 2017.

Progress on the Application of Other Countries in Becoming Associate Members of IAPWS. Four people were in attendance from the power plant cycle chemistry area in China at the IAPWS and EC meetings during the week. It is expected that an application for China to become an Associate Member will be signed in China in the coming months.

14. Executive Secretary's Report

14.1 IAPWS Bank Accounts, Financial, Auditors and IAPWS Dues

The Executive Secretary reported that IAPWS is on a sound financial footing with currently about £64,000GBP in total in the UK and US bank accounts. The status as at

7th September 2016 in the bank accounts had been provided to each National Delegate prior to the EC meeting.

The Executive Secretary next reported that the 2015 financial statements had been forwarded to the IAPWS Auditors in January 2016. Professor Savarik in Czech Republic had reviewed and approved the financial statements. This approval had also been provided to the Heads of all the National Delegates present prior to the EC meeting. Following the distribution of the financial statements, the German Auditor, VDI, also provided approval of the accounts.

The Executive Secretary proposed that these organizations continue to act as auditors.

The EC Approved this Unanimously.

The Executive Secretary proposed to the EC that the dues structure for member countries remains unchanged for 2017. He also mentioned that IAPWS By-Law #1 provided the basis of the dues structure, and that this would be used to assess the dues for the new Member, New Zealand.

The EC Unanimously Agreed to this Proposal.

The Executive Secretary had also provided a rough estimate of the income and known planned expenditures for 2016 / 2017.

14.2 Time and Place of the 2017, 2018 and 2019 Meetings

2017 IAPWS Meetings. The Japan Delegate, Nakahara, indicated that the Japan NC will host the IAPWS meetings in Kyoto from Sunday 27th August to Friday 1st September 2017. The meetings will be held at the Kyoto Research Park (KRP). He also indicated that a number of hotels will be available for accommodation. Updated information on the meetings will be available on the website.

2018 IAPWS Meetings and the 17th ICPWS. The Head of the Czech Republic NC, Hruby, reported that the Czech Republic National Committee will organize the 17th ICPWS in Prague on 2nd to 7th September 2018 at the Prague Marriott Hotel. Hruby indicated that a Local Organizing Committee (LOC) has been formed, and the International Program Committee (IPC) was also organized and met during the Dresden week. An initial suite of symposia titles was developed by the IPC. A webpage has been established (www.icpws2018.com).

2019 IAPWS Meetings. The Executive Secretary informed the EC that Canada had been requested to consider hosting the 2019 IAPWS meetings.

15. Guidelines, Releases, Certified Research Needs, and International Collaborations

The President indicated that the Releases and ICRNs had been discussed within the WG Reports so no further action was required by the EC. Also one amendment for a current international collaboration had been discussed and approved in the TPWS report (Minute 7).

16. IAPWS Awards

16.1 IAPWS Helmholtz Award

The President reported that the 2016 Helmholtz Award was to Dr. Frédéric Caupin of Université Claude Bernard Lyon 1 et CNRS in France, and that he had presented the Helmholtz Lecture at the IAPWS Symposium on Wednesday.

Kretzschmar then asked the Japan Delegate, Nakahara, for the names of the 2017 Helmholtz Award Committee. The 2017 Helmholtz Committee will consist of: Chairman Nakahara (Japan), Orlov (Russia), Jensen (SIAPWS), Harvey (USA) and Cooper (BIAPWS).

Action: Nominations will be due to the Executive Secretary by 31st January 2017.

16.2 IAPWS Honorary Fellowships

The President reported that Dr. Allan Harvey from NIST, USA had been elected an Honorary IAPWS Fellow, following the established procedures and after unanimous approval through the postal ballot conducted by the Executive Secretary. The Fellowship Award had been presented to him at the IAPWS banquet by the IAPWS President.

Kretzschmar then reminded the EC of the Awards Committee for 2017 with Friend as Chairman and Petrova as member with the IAPWS President as ex.-officio member.

Action: Nominations are due to the Executive Secretary by 31st January 2017.

16.3 IAPWS Gibbs Award

The President reminded the EC that nominations from the Heads of NC and WG Chairs should be sent to the Executive Secretary by 31st May 2017. The selection process will take place during the Kyoto 2017 meetings.

17. Election of IAPWS Officers for 2017 and 2018

The Executive Secretary indicated that according to the Statutes, the election of the next Vice President should be made at the end of the EC meeting in even years. The President and Executive Secretary had checked the recent history, and suggest that the Czech Republic National Committee should be asked to nominate one of their committee members for the position. The Executive Secretary asked the EC if there were any other suggestions or comments. None were suggested, so he then requested the EC to approve this selection.

The EC Unanimously Approved this Selection Process.

Action: The Czech Republic National Committee should inform the Executive Secretary of their agreement to provide a nomination for Vice President after the next meeting of their committee, and before the end of November 2016.

18. New Business

18.1 Press Release

The President mentioned that Cook had been asked at the EC meeting on Monday to develop a Press Release. This was developed with input provided by each WG and SC. Cook indicated that a document had been prepared. The final version is Attachment 9. The President indicated that this release will be sent to all NCs and WGs of IAPWS and it should be distributed as widely as possible and sent to any journals and publications.

18.2 German National Committee Feedback on the Dresden Meetings.

The Conference Chair, Herrmann, thought the IAPWS meetings had been a great success with 86 full time participants, 4 additional people for two days, 9 additional people for the symposium and 11 spouces. He thanked everybody for attending. The EC applauded in thanking the German NC team for the great organization of the meetings, symposium and IAPWS Dinner.

18.3 Other New Business

President Kretzschmar asked the EC if there was any further business.

The Head of the German NC, Wagner, indicated that he would be stepping down immediately and that Weber would take over. The President thanked Wagner for all the excellent work over the many years of his involvement with IAPWS.

No other business was raised.

18.4 Reports from National Committees.

Written reports on progress in member countries were not reported to the EC but were either distributed to other members and the Executive Secretary during the IAPWS week, or sent to the Executive Secretary after the meetings. They are attached to these minutes as follows:

Argentina/Brazil	Attachment 10
Canada	Attachment 11
Czech Republic	Attachment 12
Germany	Attachment 13
Japan	Attachment 14
Russia	Attachment 15
Switzerland	Attachment 16
USA	Attachment 17

18.5 Participants

Attachment 18 provides a list of participants at the IAPWS EC and WG Meetings in Dresden, Germany in September 2016.

18.6 List of Members

An up-dated list of members of the Executive Committee, Working Groups, and Honorary Fellows will be developed by the Executive Secretary following the Dresden Meetings. This will be forwarded electronically to the Head of each National Committee and the Working Group Chairs.

19. Closing Remarks and Adjournment

The President thanked everybody for participating at this EC meeting. Then he formally closed the 2016 EC meeting at 11:58 am.

AGENDA for the EXECUTIVE COMMITTEE of IAPWS

Dresden, Germany. 11th – 16th September 2016

Monday, 11th September 2016. Opening Plenary Session (8:30 – 10:00 am)

Opening Remarks, Welcome and Introductions by IAPWS President H-J. Kretzschmar

1. Adoption of Agenda
2. IAPWS Business and Appointment of Committees
   - 2.1 Releases, Advisory Note, ICRNs and Technical Guidance Documents
   - 2.2 IAPWS Highlights / Press Release
   - 2.3 Evaluation Committee on International Collaboration
   - 2.4 IAPWS Awards Committees for 2017 (Honorary Fellow, Gibbs, Helmholtz)
   - 2.5 Numbering of IAPWS Documents (2015 Minute 17.2)
   - 2.6 17th ICPWS. Formation of International Program Committee (IPC)
   - 2.7 Overview of OPAL Website for IAPWS Documents and Presentations
   - 2.8 Other business requiring special/extensive discussions
3. EC Mandate to Working Groups and Membership
   - 3.1 Releases, Guidelines and ICRNs
   - 3.2 WG Directions
4. Preview of Week's WG Activities by WG Chairmen

Friday, 16th September 2016. Executive Committee Meeting. (9:00am – 1:00 pm)

5. Acceptance of Minutes of Previous Meeting
6. President's Report
7. Report and Recommendations of Joint TPWS, IRS and the Sub-Committee on Seawater
8. Report and Recommendations of Separate IRS Meetings
9. Report and Recommendations of Separate Sub-committee on Seawater Meetings
10. Report and Recommendations of PCAS
11. Report and Recommendations of PCC
12. Editorial Committee Report
13. Membership and Associates
    - 13.1 Report on Membership. Including Members Defaulting on Dues.
    - 13.2 Application of New Zealand as a Member of IAPWS
    - 13.3 Application of Egypt as an Associate Member of IAPWS
    - 13.4 Report of Current Associate Members, Australia and Switzerland
14. Executive Secretary's Report
    - 14.1 IAPWS Bank Accounts, Financials, Auditors and Dues
    - 14.2 Time and Place of 2017 and 2019 Meetings.
      Includes Czech Republic on the 17th ICPWS in 2018
15. Guidelines, Releases, Certified Research Needs, and International Collaborations
    - 15.1 International Collaborations
16. IAPWS Awards
    - 16.1 Helmholtz Award Committee
    - 16.2 Honorary Fellowship
    - 16.3 Gibbs Award
17. Election of Officers for 2017 and 2018
18. New Business
    - 18.1 Press Release
    - 18.2 German Committee feedback on 2016 Meetings and Symposium
    - 18.3 Other items raised during the IAPWS week
19. Adjournment

Schedule of IAPWS Meetings

Dresden, Germany. 11th – 16th September 2016

(All technical meetings will be in the Steigenberger Hotel de Saxe, Dresden, Germany)

Sunday 11 Sept.	7:00 – 10:00 pm	Informal Get-together and Registration
Monday 12 Sept.	8:30am	**Executive Committee - Opening Plenary Session**
	10:00am	Coffee / Tea Break
	10:30am	TPWS/IRS/SCSW Joint Meeting
		(To set agendas for the week and to conduct IAPWS Business, thus allowing remainder of week for technical matters)
	10:30am	PCAS and PCC Separate Meetings
		(To conduct IAPWS Business, thus allowing remainder of week for technical matters)
	12:00pm	Lunch
	1:30pm.	TPWS/IRS/SCSW Joint Meeting
	1:30pm.	PCC and PCAS Separate WG Meetings
Tuesday 13 Sept.	8:30am	PCAS Workshop (other WG Members will be welcome)
	8:30am	PCC Workshop (other WG Members will be welcome)
	8:30am	TPWS/IRS/SCSW Joint Working Group Meeting
	10:30am	TPWS/IRS/SCSW Joint or Separate Meetings
	10:30am	PCC and PCAS Separate Meetings
	12:00pm	Lunch
	1:30pm	TPWS/IRS/SCSW Joint Meeting.
	1:30pm	PCC/PCAS Joint WG Meeting and Workshop
	3:30pm	PCC and PCAS Separate Meetings
Wednes. 14 Sept.	8:30 – 1:30	**IAPWS Symposium**
		(Steam, Water and Aqueous Mixtures in Energy and Process Engineering)
	2:30 – 5:00	**Technical Visit**
		(DREWAG - Stadtwerke Dresden GmbH)
Thursday 15 Sept	8:30am	IRS, SCSW and PCC Separate WG Meetings
	8:30am	TPWS/PCAS Joint WG Meeting
	12:00pm	Lunch
	1:30pm	Separate meetings of Working Groups
		(If needed to prepare for Executive meeting)
	6:30pm.	**IAPWS Dinner/Banquet**.
		(Europa Ballroom of the Hilton Hotel Dresden)
Friday 16 Sept.	9:00am	**Executive Meeting (9:00am - 1: 00pm)**
		(Will include at least one member from each National Delegation)

TPWS - Thermophysical Properties of Water and Steam WG
SCSW - Subcommittee on Seawater
IRS - Industrial Requirements and Solutions WG
PCAS - Physical Chemistry of Aqueous Solutions WG
PCC - Power Cycle Chemistry WG

Barry Dooley
16th September 2016

2016 IAPWS Symposium

Steam, Water and Aqueous Mixtures in Energy and Process Engineering

Dresden, 14 September 2016

Prof. Dr. Hans-Joachim Kretzschmar, Chair of the local organizing committee,
Welcome.

Uwe Gaul, State Secretary of the Saxon State Ministry of Science and Art,
Opening Remarks.

Prof. Dr. Hans-Joachim Kretzschmar, IAPWS President,
2016 IAPWS Helmholtz Award presentation.

Helmholtz Award Lecture
Dr. Frédéric Caupin, University of Lyon, France,
How I met your water.

Dr. Ernst-Günter Hencke, VDI Düsseldorf, Germany,
VDI Standards for Energy Technology.

Prof. Dr. Johannes Janicka, University of Darmstadt, Germany,
The German Energy Transformation after the Paris Conference: A Global Rule-Model?

Dr. Vincent Holten, Dr. Frédéric Caupin, University of Lyon, France,
J. V. Sengers, M. A. Anisimov, University of Maryland, College Park, MD, USA,
Thermodynamics of Metastable Water.

Prof. Dr. Roland Span, Ruhr University Bochum, Germany,
Carbon Dioxide / Water – Describing a System with Rather Unique Thermodynamic Properties.

Prof. Dr. Ullrich Hesse, Dr. Robin Langebach, Dresden University of Technology, Germany,
R718 – Water as a Refrigerant.

Prof. Dr. Eckhard Vogel, Dr. Sebastian Herrmann, Benjamin Jäger,
Dr. Robert Hellmann, Dr. Eckard Bich, University of Rostock, Germany,
Interplay of Experimental and Theoretical Transport Property Research for Working Fluids in Power Engineering.

Prof. Dr. Jadran Vrabec, Dr. Gabriela Guevara-Carrion, Tatjana Janzen, Andreas Köster,
University of Paderborn, Germany,
Thermodynamic Properties of Water and Aqueous Alcohol Mixtures by Molecular Simulation.

Dr. Rutger. Kretschmer, DREWAG Dresden, Germany,
DREWAG - The Dresden Energy Supplier.

Technical Visit at DREWAG Dresden

Minutes:

IAPWS Thermophysical Properties of Water and Steam WG

Dresden, Germany, 12–15 September 2016

NOTE: These Minutes include many items that were held jointly with the IRS Working Group and/or the Subcommittee on Seawater (SCSW). Items are listed according to their order on the TPWS agenda, which is Attachment A. **Bold print** denotes significant actions.

Obituary: W. Wagner reported that Dr. P. Hill, former member of TPWS, died. Phil Hill was born in Vancouver in 1932. He studied at Queen's University in Kingston (Canada). After completing his PhD at MIT (USA), he taught at Queen's University at Kingston (Canada). He returned to Vancouver in 1975 and became Professor at the Department of Mechanical Engineering of the University of British Columbia. He retired in 1997. Phil Hill is coauthor of the famous Steam Tables authored by Keenan, Keyes, Hill, and Moore, published in 1969. In 1982, he published an article on the equation of state for heavy water of which the release was adopted by IAPWS in 1984. He also developed an equation of state for ordinary water published in the J. Phys. Chem. Ref. Data in 1990. He had been active in TPWS until 1996. Besides this, he co-authored many papers and a textbook on turbomachinery propulsion. In 1995, he co-founded Westport Innovations Inc., a company specialized in alternative fuel for transportation and industrial machinery. There, he worked until very shortly before his death.

1-2. The meeting was opened on Monday, September 12, 2016 by the TPWS Chair, Allan Harvey. The agenda (Attachment A) was adopted after some additions. The Chair noted that the 2015 Minutes had been circulated and approved by email shortly after the 2015 meeting. J. Hrubý was appointed Clerk of Minutes for TPWS. (Olaf Hellmuth was appointed Clerk for SCSW and Adam Nový for IRS.)

3. No new Collaborative Project was suggested at TPWS. Collaborative Project "Towards an IAPWS Guideline for the Thermodynamic Properties of Supercooled Heavy Water" was approved at the 2015 IAPWS meeting as a collaboration between the Czech and US national committees. A young scientist, Dr. M. Duška, started his stay at Maryland University. As a result of a substantial change of the exchange rate with GBP, the IAPWS subsidence in USD significantly dropped so that the fulfillment of the project is threatened. A motion to recommend to the EC an amendment of this project increasing the IAPWS subsidence to balance the exchange rate loss was approved by TPWS (no vote against, one abstained). **The Working Group (jointly with SC SW and IRS) requests that the EC authorize additional funds toward the collaborative project "Toward an IAPWS Guideline on the Thermodynamic Properties of Supercooled Heavy Water" which was approved in 2015 and allocated 17,490 GBP. It is requested that the amount allocated to this project be increased by an amount (to be calculated by the Executive Secretary) to make the total number of US dollars available now equal to the number of US dollars that the original allocation would have bought at the time of the Stockholm meeting.**

NOTE: Items 4 and 5 are reported on in the IRS minutes.

4. Industrial Requirements and Solutions for Steam Property Calculations, joint with WG IRS

4.1 Report of the Task Group "Industrial Advisory Note" (M. Hiegemann, B. Rukes, A. Singh, A. Harvey)

4.2 Large eddy simulation of condensing steam in a turbine cascade (P. Post, F. di Mare)

5. Editorial Changes for IAPWS Industrial Documents (joint with WG IRS and SC SW)

5.1 Report on proposed Editorial Changes on the Revised Supplementary Release on Backward Equations for Specific Volume as a Function of Pressure and Temperature v(p,T) for Region 3 of the IAPWS Industrial Formulation 1997 (M. Kunick, H.-J. Kretzschmar, W. Wagner, A. H. Harvey)

5.2 Formal consideration of the Editorial changes to the Supplementary Release

5.3 Report of proposed editorial changes to Advisory Note 5: Industrial Calculation of the Thermodynamic Properties of Seawater (S. Herrmann, H.-J. Kretzschmar, K. Orlov)

5.4 Formal consideration of the Editorial changes to the Advisory Note

6. Heavy Water Properties (joint with WG IRS)

6.1 S. Herring reported on behalf of the Task Group on Heavy Water Thermodynamic Properties (other members R. Span, A. Harvey). The work started in 2013 as a collaborative project between NIST and Ruhr Universität Bochum. A preliminary EoS was developed in 2014. Since then, new data for speed of sound for liquid heavy water has been obtained and the second virial coefficient has been computed quantum mechanically down to 200 K. These new data were included in a new version of the thermodynamic formulation. The equation is valid up to 825 K and 1200 MPa. Behavior in the liquid-vapor critical region has been improved. Not yet available are calculated data for the ideal gas properties and the third virial coefficient and experimental data for supercooled liquid density. In the following discussion, it was stressed that the work needs to be finished soon. It has been decided that new data can only be included in the formulation if provided before the end of 2016. The formulation should be provided to the Evaluation Task Group by the end of May 2017.

6.2 Evaluation Task Group for Heavy Water Formulation, including H.-J. Kretzschmar (Chair), M. Duška, and co-opted expert Thomas Beuthe (AECL, Canada), has been appointed in Moscow at the 2014 IAPWS Meeting. V. Holten and J. Hrubý were nominated as additional members of the Evaluation Task Group. The Evaluation Task Group should provide a report by the end of July, 2017.

6.3 Report of TG for Heavy Water Transport Properties (J. Sengers, M. Assael, M. Huber, R. Perkins). Jan Sengers reported that theoretical calculations had been received for the dilute-gas viscosity and thermal conductivity, although the thermal conductivity numbers will change slightly when new ideal-gas heat capacities are obtained. The rest of the project is on hold until the final EoS is available (c.f. item 6.1).

6.4 Measurements of the Viscosity of Supercooled D_2O (Pierre Ragueneau, Amine Dehaoui, Bruno Issenmann, Frédéric Caupin). Brownian motion diffusion coefficient of polystyrere spheres (400 nm dia.) was studied to obtain the viscosity through the Stokes-Einstein relation (with calibration at 20 °C where the viscosity is well known). Earlier results from others using

smaller diameter capillaries were probably distorted by an unappreciated artefact. D_2O and H_2O and their mixtures were studied.

6.5 J. Hrubý reported on measurements of the density of supercooled D_2O up to 100 MPa (co-authors M. Duška, P. Peukert, V. Hykl, V. Vinš). The experimental technique is based on observation of the change of height of a liquid column in two fused silica capillaries. The important improvements of the technique, the calibration of the capillaries and removing the polyimide protective layer, were reported. The measurements are relative to densities at corresponding pressure at 298.15 K and to density of synthetic fused silica. Moderate deviations (order of 0.1%) with respect to the current IAPWS standard were found. Final data will be provided before the end of 2016.

7. Proposed Improvements of IAPWS-95 Release

7.1 W. Wagner reported on behalf of the Task Group on Uncertainty Estimates of IAPWS-95 in Isobaric Heat Capacity (other members M. Thol, A. Harvey). In the region from 250 to 300 K and 100 to 400 MPa, an improved estimate of IAPWS-95 uncertainty for Cp was developed based on speed of sound data by Lin and Trusler. The region was divided into several subregions with increasing uncertainty towards low temperature and high pressure. A detailed report was provided to TPWS members prior to the meeting.

7.2 W. Wagner (co-authors A. Harvey, V. Holten) reported on a proposed improvement of the description of extrapolation for metastable subcooled liquid. With respect to new data available for the supercooled liquid, it was suggested that the statement about the performance of IAPWS-95 in this region be modified. In a subsequent discussion, it was suggested that also the statement for superheated water is modified by restricting extrapolation area to positive pressures.

W. Wagner announced that he has concluded his work concerning the IAPWS-95. The working groups expressed their gratitude for his devoted service.

7.3 Formal consideration of the Revised Release. A draft Revised IAPWS-95 Release has been prepared, incorporating the changes suggested in items 7.1 and 7.2. **TPWS unanimously approved the revised Release and recommended that it be sent for postal ballot by the EC following Editorial Committee review.**

8. V. Vinš reported on behalf of the Task Group on Surface Tension of Ordinary Water (other members A. Harvey, O Hellmuth, V. Holten, J. Hrubý, J. Kalová, R. Mareš, J. Pátek). The task was to review and analyze new and old literature data for surface tension and to revise the uncertainty estimates. New measurements for supercooled water using an altenative method agree with the published ones within their uncertainty. A new equation for the surface tension of water has been developed (J. Pátek, M. Součková, J. Klomfar, J. Chem. Eng. Data 61 (2016), 928−935). The equation has the form of the IAPWS Release, only the values of the parameters are modified. In the high-temperature region, the correlation relies solely on data by Voljak (1950) and Vargaftik et al. (1973), so it would be helpful if other data at high temperatures could be obtained. F. Caupin remarked that a group at Pau might have such data or be able to take them; the Task Group will investigate this.

R. Mareš reported on his measurements of surface tension for supercooled water using thin capillaries (down to I.D. 0.05 mm). An equation for the settling time has been derived. The settling time for thin capillaries approaches an hour.

B. Planková reported on computations of surface tension using molecular dynamics simulations. Anomalous temperature dependence reported in some earlier works has not been confirmed.

It was suggested, that the equation by Pátek et al. could be considered as a basis for a revised guideline. However, in the discussion it was suggested, that the equation should be adjusted to a proper value of the universal critical exponent. Also, it has been suggested that the measurements in the supercooled region are finished and that groups capable of surface tension measurements at high temperatures would be searched for. The Task Group will continue its work. **TPWS authorizes the TPWS Chair to nominate an Evaluation Task Group before the next meeting if it would help accelerate the process of finalizing a new Release.**

The possibility of a project for updating the IAPWS Release for the surface tension of heavy water was brought up, but this is not a high priority.

9. O. Hellmuth reported on the parameterization of humid air fugacity and enhancement factor. **A Task Group was formed to consider developing an IAPWS document based on recent work on an explicit approximation for the enhancement factor of water in humid air (and humid gases more generally).** The Task Group consists of O. Hellmuth (Chair), J. Hrubý, R. Feistel, A. Harvey, J. Cooper, and H.-J. Kretzschmar. More details are in the SCSW Minutes.

10. Metastable Water (joint with SC SW)

10.1 R. Romeo (co-authors S. Lago, P. A. G. Albo, S. Lorefice) presented measurements of densities of liquid water in stable and metastable (supercooled) states from 140 to 400 MPa. The measurements were performed using a modified isochoric method. Pressure of liquid in a cell with volume of about 30 cm^3 was recorded at varying temperature. The mass was determined based on IAPWS-95 by expanding the liquid at temperature higher than 0 °C into a smaller volume such that the resulting pressure was smaller than 10 MPa. The volumes of the cell and the expansion cell were determined gravimetrically. Coefficients of the linear pressure and temperature corrections of the cell volume were determined based on IAPWS-95 at temperatures higher than 0 °C. Uncertainty is estimated as 0.07 % in density. The data show a good agreement with other experiments and with IAPWS formulation for supercooled water.

10.2 J. Hrubý (co-authors M. Duška, P. Peukert, V. Hykl, V. Vinš) presented measurements of density of cold and supercooled water between 0.1 and 100 MPa using the same technique as for heavy water (c.f. item 6.5). The measurements are relative to densities at corresponding pressure at 298.15 K and to density of synthetic fused silica.

10.3 F. Caupin presented measurements of viscosity of supercooled liquid water under pressure and a two-state model interpreting these results.

10.4 J. Hrubý reported on behalf of the Task Group on Superheated Liquid Water (second member R. Feistel). Experimental data for specific volume and speed of sound of superheated water at positive pressures have been collected. A part of the data was not considered by IAPWS-95 developers. Extrapolated IAPWS-95 represents these data within the experimental uncertainty in agreement with the corresponding statement in the IAPWS-95 release (c.f. items 7.2 and 7.3)

10.5 As reported by O. Hellmuth, the Task Group on an ICRN for Interfacial Properties of Supercooled Water (other members J. Hrubý, J. Sengers), did not have any activity. The TG will continue with the same task.

10.6. V. Holten reported on behalf of Task Group on possible revision of IAPWS formulations for melting curves (other members A. Harvey, H.-J. Kretzschmar). The present equations are mostly based on old Bridgman data. Holten developed models of Gibbs energy of ices II, III, V, VI, enabling, in connection with an equation for the liquid phase, calculation of the phase diagram. Ice Ih was represented with the IAPWS formulation. Liquid water was represented by the supercooled water IAPWS formulation below 890 MPa and by IAPWS-95 at higher pressures. Linear temperature and pressure dependence of volume turned out to be insufficient. Final model is based on Birch/Murnaghan equation of state with 6 adjustable parameters for each ice phase. The task group will continue its work towards an improved model to replace the current IAPWS formulation for melting curves. It is hoped that the revision will be ready for IAPWS adoption in 2017.

NOTE: Items 11–14 are reported on in the SCSW Minutes.

11. Report of Task Group on Extension of Range of Formulation for Thermodynamic Properties of Sea Water (joint with WGs IRS and SC SW) (R. Feistel)

12. Cooperation with other international bodies (joint with SC SW)

12.1 IAPWS/IAPSO/SCOR Joint Committee on Seawater, including updates to TEOS-10 (R. Pawlowicz)

12.2 Metrologia articles on BIPM/IAPWS interaction (R. Feistel)

12.3 Possible ISO work on (possibly impure) water for calibration and produced water properties for the oil industry.

13. Reports on seawater-related topics (joint with SCSW)

13.1 A standard for seawater sample handling (G. Budeus)

13.2 Thermophysical Properties of Natural Seawater samples (J. Safarov, A. Mirzalyiev, E. Hassel)

13.3 CO_2 Solubility in Seawater at wide range of salinities. (J. Safarov, S. Berndt, F.J. Millero, R. Feistel, A. Heintz, E. Hassel)

13.4 Update of the EMPIR project (S. Seitz and D. Stoica)

13.5 Absolute salinity and density using a hydrostatic weighting apparatus and using in-situ sound velocity sensors (H. Uchida)

13.6 Chinese Standard Seawater (Y. Li)

13.7 Salinity anomalies – Arctic Rivers and hydrothermal vents (R. Pawlowicz, H. Uchida, R. Woosley, F. Millero)

13.8 Salinity anomalies – a decade in the Baltic (S. Weinreben)

14. Proposed new IAPWS seawater-related documents (joint with SCSW)

14.1 Report on Guideline for Electrical Conductivity of Seawater (R. Pawlowicz)

14.2 Report of Task Group on Supplementary Release for a simplified density equation for oceanographic use (R. Pawlowicz, T. McDougall, P. Barker)

14.3 Report of Task Group on Advisory Note on IAPWS documents contributing to TEOS-10 (R. Feistel, A. Harvey, R. Pawlowicz)

14.4 Formal consideration of Advisory Note on TEOS-10.

15. Reports on miscellaneous TPWS scientific topics (joint with WG IRS and SC SW)

15.1 R. Feistel contributed to the discussion of the Task Group on Covariance in IAPWS work (other members J. Hruby, S. Seitz, J. Lovell-Smith, D. Friend). An article on the Uncertainty of Empirical Correlation Equations has been published (Metrologia 2016). When the covariance matrix of regression parameters is available, it is possible to estimate uncertainty of any property derived from the model. The method has been applied to the IAPWS-95 formulation. Uncertainty of second and third virial coefficients were estimated and these estimates were an order of magnitude smaller than an expert's estimates. In following discussion, it has been stressed that this failure is primarily due to neglecting non-diagonal terms in the covariance matrix of experimental data. However, no methodology is available for estimating them. Other contributors expressed skeptical opinions to the covariance method. However, it was generally accepted that it is desirable to improve the methods for uncertainty estimates. **A motion has been made that TPWS members developing a correlation are recommended to provide also the covariance matrix for the regression coefficients. This motion was approved.**

16. Joint session between TPWS and PCAS

16.1 J. Hrubý reported on the progress toward improved ideal-gas properties of ordinary and heavy water. The groups of A. Csaszar and J. Tennyson have completed a database of rotational-vibrational energy levels for important water isotopologues. The partition function and ideal gas thermodynamic properties are obtained from the energy levels in a straightforward manner. Data for the most abundant isotopologue $H_2{}^{16}O$ are being published. Data for $D_2{}^{16}O$ will be available soon. Less accurate data for the minor isotopologues will be also provided.

16.2 A. Harvey reported on behalf of the Task Group on Isotopic Fractionation (further members R. Feistel, D. Friend, J. Hrubý, K. Meier). Isotopic fractionation, i.e., unequal fractions of different isotopes (hydrogen or oxygen) between two phases in contact, is important, e.g., for tracing flows of matter in geophysical research. Isotopic fractionation can be of thermodynamic origin (isotopic effect on chemical potentials) or kinetic origin (effect on diffusion coefficients). Liquid-vapor, vapor-solid, liquid-solid fractionation were considered. Reliable correlations are partly available. At present, it appears that IAPWS cannot efficiently contribute to this field. The Task Group will continue, but is not assigned any tasks in the coming year.

16.3 S. Hielscher (co-authors A. Jäger, V. Vinš, R. Span, J. Hrubý, C. Breitkopf) reported on the progress in modeling gas hydrates relevant for carbon capture and storage. The model is based on the molecular model originally due to van der Waals and Platteuw for the hydrate and reference equations of state for the fluid phases and pure crystalline phases (ice Ih and dry ice). The model provides a better description of the phase equilibria with other fluid and solid phases. First results have been produced for a mixed hydrate system with variable fraction of methane and carbon dioxide guests in the clathrate matrix of water molecules.

16.4 M. Nakahara talked about the transformation from carbon-based chemical energy to hydrogen-based chemical energy. He discussed formic acid as a possible liquid carrier of hydrogen for such uses.

17. IAPWS Certified Research Needs (ICRNs)

ICRN 27 (on humid gases and CO_2-rich mixtures) was allowed to expire at the 2014 meeting, but a closing statement is still needed. R. Span and A. Harvey will provide this statement.

18. Reports on other TPWS activities

18.1 A. Harvey proposed an update of the Guideline on Fundamental Constants. The revision reflects an update of the values of fundamental physical constants (CODATA 2014) and recent evaluation of atomic weights. Further, a reference to the new Standard Mean Ocean Water (VSMOW2) was added. The changes do not have significant effect on IAPWS documents. **The update was approved unanimously.**

18.2 A. Harvey (co-author J. Cooper) reported on Advisory Note 2 "Roles of various IAPWS documents." **Minor updates in the document were approved unanimously, to be implemented by Harvey and Cooper in the coming months.**

18.3 M. Kunick informed about the completion and adoption of the IAPWS Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method SBTL (M. Kunick, H.-J. Kretzschmar, F. di Mare, J. Hrubý, V. Vinš, I. Weber, R. Pawellek, A. Nový, A., D.G. Friend, and A.H. Harvey). The Guideline was adopted by IRS and TPWS at the 2015 Meeting, become official by March 31, 2016. The SBTL method has been implemented in software TRACE (CFD software DLR, Germany), Krawal and Dynaplant, Power Plant Siemens, Ebsilon. Other applications are being developed.

19. Other Business

19.1 Report on International Collaborative Projects: Project approved at the previous meeting (Czech-US) just started, it will be reported on in 2017.

19.2 **D. Friend was appointed to represent TPWS on the Gibbs Award committee**.

20. Membership: Phil Hill (deceased) is removed from membership. **Three new members of TPWS were proposed: Dr. Simona Lago (Istituto Nazionale di Ricerca Metrologica Italy), Dr. Frédéric Caupin (University of Lyon, France), Dr. Andreas Jäger, (Technische Universität Dresden, Germany). They were unanimously approved to be recommended to the EC for appointment to the Working Group.**

21. Contribution to Press Release

The chair and the clerk of minutes were assigned to prepare the contribution to the Press Release.

22. Preparation of the Formal Motion to the EC

The chair and the clerk of minutes were assigned to prepare the Formal Motion to the EC.

23. Adjournment

The meeting was adjourned at 3:15 p.m. on Thursday, September 15.

Preliminary Agenda for the IAPWS Working Group
Thermophysical Properties of Water and Steam (TPWS)

Dresden, Germany, September 12-15, 2016

1. Opening Remarks; Adoption of Agenda
2. Appointment of Clerk of Minutes
3. Potential International Collaborative Projects [Monday]
4. Industrial Requirements and Solutions for Steam Property Calculations, joint with WG IRS (Monday)
   - 4.1 Report of the Task Group "Industrial Advisory Note" (M. Hiegemann, B. Rukes, A. Singh, A. Harvey)
   - 4.2 Large eddy simulation of condensing steam in a turbine cascade (F. di Mare)
5. Editorial Changes for IAPWS Industrial Documents (joint with WG IRS and SC SW) (Monday)
   - 5.1 Report on proposed Editorial Changes on the Revised Supplementary Release on Backward Equations for Specific Volume as a Function of Pressure and Temperature v(p,T) for Region 3 of the IAPWS Industrial Formulation 1997 (M. Kunick, H.-J. Kretzschmar, W. Wagner, A. H. Harvey)
   - 5.2 Formal consideration of the Editorial changes to the Supplementary Release
   - 5.3 Report of proposed editorial changes to Advisory Note 5: Industrial Calculation of the Thermodynamic Properties of Seawater (S. Herrmann, H.-J. Kretzschmar, K. Orlov)
   - 5.4 Formal consideration of the Editorial changes to the Advisory Note
6. Heavy Water Properties (joint with WG IRS)
   - 6.1 Report of Task Group on Heavy Water Thermodynamic Properties (R. Span, A. Harvey, S. Herrig)
   - 6.2 Appointment of Evaluation Task Group for Heavy Water Formulation
   - 6.3 Report of TG for Heavy Water Transport Properties (J. Sengers, M. Assael, M. Huber, R. Perkins)
   - 6.4 Measurements of the Viscosity of Supercooled D_2O (Pierre Ragueneau, Amine Dehaoui, Bruno Issenmann, Frédéric Caupin)
   - 6.5 Measurement of the Density of Supercooled D_2O up to 100 MPa (M. Duška, J. Hrubý)
7. Proposed Improvements of IAPWS-95 Release
   - 7.1 Report of Task Group on Uncertainty Estimates of IAPWS-95 in Isobaric Heat Capacity (W. Wagner, M. Thol, A. Harvey)
   - 7.2 Report on improvement of description of extrapolation for metastable subcooled liquid (A. Harvey, V. Holten, W. Wagner)
   - 7.3 Formal consideration of the Revised Release
8. Report of Task Group on Surface Tension of Ordinary Water (joint with WG IRS and SC SW) (V. Vinš, A. Harvey, O. Hellmuth, V. Holten, J. Hrubý, J. Kalova, R. Mareš, J. Patek)

9. Humid Air Fugacity and Enhancement Factor, joint with SC SW (O. Hellmuth)

10. Metastable Water (joint with SC SW) [Tuesday]
    - 10.1 Experimental densities of water in stable and metastable states up to 400 MPa and comparison with dedicated equations of state (Raffaella Romeo, Simona Lago, P. Alberto Giuliano Albo, Salvatore Lorefice)
    - 10.2 Measurement of the density of supercooled ordinary water up to 100 MPa (M. Duška, J. Hrubý)
    - 10.3 Measurement of viscosity in supercooled water and representation with a two-state model (F. Caupin)
    - 10.4 Report of Task Group on Superheated liquid water, joint with WG IRS and SCSW (J. Hrubý, R. Feistel)
    - 10.5 Report on Task Group on ICRN for Interfacial Properties of Supercooled Water (O. Hellmuth, J. Hrubý, J. Sengers)
    - 10.6 Report of Task Group on possible revision of IAPWS formulations for melting curves (V. Holten, A. Harvey, H.-J. Kretzschmar)

11. Report of Task Group on Extension of Range of Formulation for Thermodynamic Properties of Sea Water (joint with WGs IRS and SC SW) (R. Feistel) (Tuesday)

12. Cooperation with other international bodies (joint with SC SW) (Tuesday)
    - 12.1 IAPWS/IAPSO/SCOR Joint Committee on Seawater, including updates to TEOS-10 (R. Pawlowicz)
    - 12.2 Metrologia articles on BIPM/IAPWS interaction (R. Feistel)
    - 12.3 (ADDED) Possible ISO work on (possibly impure) water for calibration and produced water properties for the oil industry.

13. Reports on seawater-related topics (joint with SCSW) (Tuesday)
    - 13.1 A standard for seawater sample handling (G. Budeus)
    - 13.2 Thermophysical Properties of Natural Seawater samples (J. Safarov, A. Mirzalyiev, E. Hassel)
    - 13.3 CO_2 Solubility in Seawater at wide range of salinities. (J. Safarov, S. Berndt, F.J. Millero, R. Feistel, A. Heintz, E. Hassel)
    - 13.4 Update of the EMPIR project (S. Seitz and D. Stoica)
    - 13.5 Absolute salinity and density using a hydrostatic weighting apparatus and using in-situ sound velocity sensors (H. Uchida)
    - 13.6 Chinese Standard Seawater (Y. Li)
    - 13.7 Salinity anomalies – Arctic Rivers and hydrothermal vents (R. Pawlowicz, H. Uchida, R. Woosley, F. Millero)
    - 13.8 Salinity anomalies – a decade in the Baltic (S. Weinreben)

14. Proposed new IAPWS seawater-related documents (joint with SCSW)
    - 14.1 Report on Guideline for Electrical Conductivity of Seawater (R. Pawlowicz)
    - 14.2 Report of Task Group on Supplementary Release for a simplified density equation for oceanographic use (R. Pawlowicz, T. McDougall, P. Barker)

14.3 Report of Task Group on Advisory Note on IAPWS documents contributing to TEOS-10 (R. Feistel, A. Harvey, R. Pawlowicz)

14.4 Formal consideration of Advisory Note on TEOS-10.

15. Reports on miscellaneous TPWS scientific topics (joint with WG IRS and SC SW)

15.1 Report of Task Group on Covariance in IAPWS work (R. Feistel, J. Hruby, S. Seitz, J. Lovell-Smith, D. Friend)

16. Joint session with WG PCAS [Thursday morning]

16.1 Progress toward improved ideal-gas properties of ordinary and heavy water (J. Hrubý)

16.2 Report of Task Group on Isotopic Fractionation (R. Feistel, D. Friend, A. Harvey, J. Hrubý, K. Meier)

16.3 Progress in modeling gas hydrates relevant for CCS using reference equations of state and extension of the model for mixed hydrates (S. Hielscher, A. Jäger, V. Vinš, R. Span, J. Hrubý, C. Breitkopf)

16.4 Carbon today and hydrogen in the future for chemical energy (M. Nakahara)

17. IAPWS Certified Research Needs (ICRNs)

17.1 ICRN 27: Thermophysical Properties of Humid Gases and CO_2-Rich Mixtures (closing statement needed) (R. Span, A. Harvey)

18. Reports on other TPWS activities

18.1 Guideline on Fundamental Constants (A. Harvey)

18.2 Advisory Note 2 (J. Cooper, A. Harvey)

18.3 Completion and adoption of the IAPWS Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method SBTL (M. Kunick, H.-J. Kretzschmar, F. di Mare, J. Hrubý, V. Vinš, I. Weber, R. Pawellek, A. Novi, A., D.G. Friend, and A.H. Harvey)

19. Other Business

19.1 Report on International Collaborative Projects

20. Membership

21. Contribution to Press Release

22. Preparation of the Formal Motion to the EC

23. Adjournment

A.H. Harvey (Chair), J. Hrubý (Vice-Chair)

Minutes of the IAPWS working group IRS

Dresden, 12. – 15. September 2016

(Numbering of topics follows TPWS agenda)

0. W. Wagner, in memory of Professor P.G. Hill

1. Ingo Weber opened the session for IRS at about 10:15 am, 12. September 2016. The agenda was adopted without changes.

2. Adam Nový was appointed clerk of minutes.

3. Covered in TPWS / SCSW minutes.

4. Industrial Requirements and Solutions for Steam Property Calculations

4.1. Report of the Task Group “Industrial Advisory Note”

Ingo Weber gave information, that M. Hiegemann could not be present and no progress in project is known.

TODO: I. Weber will check the status from M. Hiegemann, and the plan for the next year, otherwise the task is to be closed. H.J. Kretzschmar proposed for obtaining possible input from PCC group to be suggested to M. Hiegemann.

4.2. Large Eddy simulation of condensing steam in turbine cascade

F. di Mare from DLR institute gave a presentation on LES where efficient tabular description of thermodynamic properties is usable for solving complex problems using scale independent statistical modeling. It was the application of SBTL into CFD code done with help of M. Kunick and H.J. Kretzschmar. It was reported significant speed up compared to conventional IAPWS-IF97 and also the advantage of smooth phase and regions boundaries for minimizing convergence issues. Future perspective for high order, shock resolving calculations with explicit discretization for LES. Try similar approach to combustion and supercritical cycles.

Discussion: J. Cooper comments to consider droplets simulation approaches

5 - 15. Covered in TPWS / SCSW minutes.

16-IRS. Discussion on the future of IRS

16.1. IRS mission and activities

N. Okita presented possible areas of interest regarding the IRS group focus. The areas of possible support and particular topics presented were put together by Japanese National Committee and the Toshiba company. There were three main IRS goals highlighted.

A. Identify and prioritize industrial requirement
B. Deliver solutions
C. Support implementation

There were also specific areas of interest outlined including: wet steam (flow analysis, wetness measurement, erosion), frost/defrost/freezing/antifreezing (phase change study and molecular simulation) and thermal ice storage (static, slurry). Some topics are partially covered by existing ICRNs some not.

Discussion: B. Rukes pointed out, that many topics are being new to IAPWS and it is not sure if IAPWS wants to deal with it and that IRS should focus on topics already in scope of IAPWS. H. J. Kretzschmar came with idea of attracting new researchers and people for the next meeting/conference. I. Weber suggested to prepare list of topics properly categorized for the next meeting, based on the presentation of N. Okita, this leading to TG setup. Other discussed topic was the wet steam, IRS concluded to setup TG to find out how the properties are calculated in the industry.

TODO:

TG: N. Okita, I. Weber: internal IAPWS survey to be available to every IRS member. The target is to collect, sort and categorize "items" and evaluate the distance to IAPWS business and what kind of people is needed to solve it. Starting point will be the categories to be presented to IRS members.

TG: I. Weber, H.J.Kretzschmar, N.Okita, A. Nový: Wet steam properties survey, with target of finding out, how are in practical (industry companies) calculated/estimated the properties of wet steam, especially speed of sound, viscosity, thermal conductivity, etc.

17-IRS. IAPWS Certified Research Needs (ICRNs)

N. Okita presented potential ICRN topics based on items presented in 16.1. It was decided not to go forward with specific ICRNs until the needs are properly sorted and addressed by the IRS.

18. Covered in TPWS / SCSW minutes.

19. Other business:

19.1. no report on International Collaboration Projects

19.2 IRS voted on Ingo Weber to be the IRS representative for the Gibbs Award Committee

20. Membership

Tobias Loew (Germany) was proposed as new IRS member by H. J. Kretzschmar and seconded by R. Pawelek

IRS unanimously accepted this new member

21. Election of new chair for IRS

I. Weber steps down after 6 years of excellent work, I. Weber proposing usual chairmanship rotation. As a new chair proposed N. Okita (Toshiba) and Vicechair A. Nový (Doosan Skoda Power).

Proposal was unanimously accepted by IRS and be suggested to EC

22. Contribution to Press release will be done by the WG chair

23. Formal motion to the EC will be prepared by the WG chair

24. The IRS meeting was adjourned 15. September 2016, about 3:10 pm.

Agenda for the IAPWS Working Group
Industrial Requirements and Solutions (IRS)
Dresden, Germany, September 12-15, 2016

(Numbering of topics follows TPWS agenda, except where denoted "…-IRS")

1. Opening Remarks; Adoption of Agenda
2. Appointment of Clerk of Minutes
3. Potential International Collaborative Projects [Monday]
4. Industrial Requirements and Solutions for Steam Property Calculations, joint with WG TPWS (Monday)
   - 4.1 Report of the Task Group "Industrial Advisory Note" (M. Hiegemann, B. Rukes, A. Singh, A. Harvey)
   - 4.2 Large eddy simulation of condensing steam in a turbine cascade (F. di Mare)
5. Editorial Changes for IAPWS Industrial Documents (joint with WG TPWS and SC SW) (Monday)
   - 5.1 Report on proposed Editorial Changes on the Revised Supplementary Release on Backward Equations for Specific Volume as a Function of Pressure and Temperature v(p,T) for Region 3 of the IAPWS Industrial Formulation 1997 (M. Kunick, H.-J. Kretzschmar, W. Wagner, A. H. Harvey)
   - 5.2 Formal consideration of the Editorial changes to the Supplementary Release
   - 5.3 Report of proposed editorial changes to Advisory Note 5: Industrial Calculation of the Thermodynamic Properties of Seawater (S. Herrmann, H.-J. Kretzschmar, K. Orlov)
   - 5.4 Formal consideration of the Editorial changes to the Advisory Note
6. Heavy Water Properties (joint with WG TPWS)
   - 6.1 Report of Task Group on Heavy Water Thermodynamic Properties (R. Span, A. Harvey, S. Herrig)
   - 6.2 Appointment of Evaluation Task Group for Heavy Water Formulation
   - 6.3 Report of TG for Heavy Water Transport Properties (J. Sengers, M. Assael, M. Huber, R. Perkins)
   - 6.4 Measurements of the Viscosity of Supercooled D_2O (Pierre Ragueneau, Amine Dehaoui, Bruno Issenmann, Frédéric Caupin)
   - 6.5 Measurement of the Density of Supercooled D_2O up to 100 MPa (M. Duška, J. Hrubý)
8. Report of Task Group on Surface Tension of Ordinary Water (joint with WG IRS and SC SW) (V. Vinš, A. Harvey, O. Hellmuth, V. Holten, J. Hrubý, J. Kalova, R. Mareš, J. Patek)

11. Report of Task Group on Extension of Range of Formulation for Thermodynamic Properties of Sea Water (joint with WGs TPWS and SC SW) (R. Feistel) (Tuesday)

15. Reports on miscellaneous TPWS scientific topics (joint with WG TPWS and SC SW)

15.1 Report of Task Group on Covariance in IAPWS work (R. Feistel, J. Hruby, S. Seitz, J. Lovell-Smith, D. Friend)

16-IRS. Discussion on the future of IRS [Thursday morning]

16.1 IRS mission and activities (N. Okita)

17-IRS. IAPWS Certified Research Needs (ICRNs)

17.1 Potential new ICRNs (N. Okita)

18. Reports on other TPWS activities

18.1 Guideline on Fundamental Constants (A. Harvey)

18.2 Advisory Note 2 (J. Cooper, A. Harvey)

18.3 Completion and adoption of the IAPWS Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method SBTL (M. Kunick, H.-J. Kretzschmar, F. di Mare, J. Hrubý, V. Vinš, I. Weber, R. Pawellek, A. Novi, A., D.G. Friend, and A.H. Harvey)

19. Other Business

19.1 Report on International Collaborative Projects

19.2 Gibbs Award Committee Representative

20. Membership

21-IRS. Election of new chair for IRS

22-IRS. Contribution to Press Release

23-IRS. Preparation of the Formal Motion to the EC

24-IRS. Adjournment

September 15, 2016

I. Weber (Chair)

Minutes of the joint meeting of TPWS/IRS/SCSW

Clerk of Minutes of SCSW: Olaf Hellmuth, Dresden, June 15, 2016

1. Opening remarks; adoption of agenda:
The session was opened by Alan Harvey. The agenda was corrected by addition of **item 12.3** concerning an ISO request on work properties for calibration in the oil industry (talk given by Rich Pawlowicz).

Prof. Kretzschmar informed the attendees of Prof. Phil Hill, British Columbia, who passed since the last IAPWS meeting in Stockholm. Prof. Wolfgang Wagner remembered the great contributions of Phill Hill to the work on the International Steam Table, the EoS of ordinary and heavy water, his activities in the WG TPWS and as a member of Westport Innovations Inc. Prof. Wagner characterized Phil Hill as a "gentleman through and through".

2. Clerk of minutes:
Jan Hruby for TPWS, Ingo Weber for IRS, Olaf Hellmuth for SCSW.

3. International collaborative projects:
The working groups recommend the EC to enhance the financial support for M. Duzka, Czech Republic, to continue the work on the EoS of heavy water in U.S. at the University of Maryland (group of Prof. M. Anisimov and J. Sengers). The planned regular budget was negatively affected by sudden currency exchange disturbances in the context of the Brexit decision. The EC is asked for compensation of the effective loss in the value of available Dollars required to continue with the work.

In the following, the minutes of the SCSW related issues of the joint TPWS/SCSW sessions are listed. The numbering corresponds to those in the **"Preliminary Agenda for the IAPWS Working Group Thermophysical Properties of Water and Steam (TPWS), Dresden, Germany, September 12-15, 2016".** Items 1 to 8 belong to TPWS and IRS issues. Highlighted details are fort he report to the EC.

9. Working group report on humid air fugacity and enhancement factor (by O. Hellmuth)
A new virial approximation of the enhancement factor of water in humid air and the water vapour mole fraction in saturated humid air, respectively, has been proposed. The difference between the approximative and numerical solutions of the underlying thermodynamic model was found to be statistically not significant and by an order of magnitude lower than the difference between the previous fitted Greenspan expansion (analytical form) of the enhancement factor and the underlying thermodynamic model of Hyland and Wexler. From an uncertainty analysis based on Monte-Carlo simulations it was found that the difference between relative fugacity and relative humidity is statistically significant already at atmospheric pressure. It was shown that the consideration of real-gas effects in the humidity determination at atmospheric pressure leads to an increment in the latent heat flux which is by a factor of 500 larger than the energy flux increment required to cause a global warming of 0.5 K per 30 years. Proper resolution of global-warming effects in the oceanic evaporation rates will definitively require real-gas effects in the marine atmosphere to be allowed for.
A task group (members: O. Hellmuth, R. Feistel, A. Harvey, J. Hruby, J. Cooper) was established to formulate the requirements and content of a possible IAPWS guideline as a contribution to realise the roadmap fixed at the ICPWS 2013 workshop on humidity and to support the further cooperation of IAPWS with BIPM.

11. Report of the task group on the extension of range of formulation for thermodynamic properties of seawater (by R. Feistel)
The works aim at extension the TEOS-10 standard to higher temperatures (up to 313 K), to higher pressures (up to 60 MPa) and to higher salinities (up to 45 k/kg). New speed-of-sound data are provided by Lago et al. (2015), and new vapor pressure data by J. Safarov). New measurement data are also expectable from PTB Braunschweig. **The task group is ordered to continue its work.**

12.1. IAPWS/IAPSO/SCOR activities (by Rich Pawlowicz)
An open point on the agenda is the finalization of an "best practise guide" for high-precision density measurements by pooling collective experience. This task has high priority.
The next BIPM-CCT meeting is postponed to spring 2017. SCSW recommends to EC that IAPWS support sending a representative to this meeting (as was approved at the 2015 IAPWS-EC meeting).

12.2 IAPWS/BIPM cooperation (by R. Feistel)
The speaker presented a time series on the citation number of the joint IAPWS/BIPM Metrologia position paper on metrological needs for SI-compatible definition of salinity, pH value, and relative humidity. By 10 September 2016, the following citation numbers has been reached:
(a) Part 1: overview: 2887; Part 2: salinity: 1763; Part 3: pH value: 1821; Part 4: RH: 3714; This makes these papers the most downloaded in Metrologia at present.
At TEMPMEKO 2016 Lovell-Smith, Feistel and Hellmuth gave a presentation on the topic "Toward a general definition of RH" (including the so-called extended range defined by the constraint $p < e_{w,sat}(T)$.

12.3 ISO requests for IAPWS assistance on use of water in petroleum industry (by Rich Pawlowicz)
They have a list of requirements for density correction factors as function of T aiming at the use of TEOS-10 also for natural waters like rivers and lakes which are of interest for oil exploration. Among the requirements the extension of the range of validity of TEOS-10 (temperature up to 95°C, salinity up to 140 g/kg; need for extented range isothermal compressibility) is listed as well as the availability of user friendly equations etc. The proposed list also includes possible research projects the oil industry is interested in. In order to specify the questions of common interest, especially the applicability of TEOS-10 to lakes and rivers, a task group is established to give detailed and hopefully positive answers to the ISO TG28 SC 2 WG4 chairman of the oil industry.
The task group (members: Rich Pawlowicz, Rainer Feistel, Andrey Anderko, Allan Harvey, Olaf Hellmuth) shall give a detailed reply, formulate items of common interests and to ask for the possibilities to provide some financial support. A representative of that ISO TG28 SC 2 WG4 working group should be invited to the next IAPWS meeting for further discussion of specific research targets.

13. Reports on seawater related topics

13.1 Seawater sampling handling (by G. Budeus)
The speaker gave an overview of his measurement program in seawater salinity and density and highlighted a number of sample handling problems that he has noticed though the use of his high-resolution instruments. His suggestions are worthy of attention. Several members of the audience noted that they also experienced the problem of outgassing and bubble formation from the sampling probes in particular.

13.2 Thermophysical properties of natural seawater (by J. Safarov)
The speaker gave an overview of his labs capabilities to measure a variety of thermophysical properties in natural waters from oceans and lakes.

13.3 CO_2 solubility in seawater at wide range range of salinities (by J. Safarov)
The speaker discussed the solubility of CO_2 in natural waters.

13.4 Updates of the EMPIR project (by S. Seitz)
This talk has been withdrawn. However, S. Seitz has requested a letter of support from IAPWS for his upcoming EMPIR project proposal. SCSW will propose that the EC supports this with a letter signed by the IAPWS president.

13.5. Absolute salinity and density using a hydrostatic weighing apparatus and using in situ sound velocity sensors (by H. Uchida).
Although Uchida was not present his colleague Y. Kayukawa presented preliminary results of his hydrostatic weighing measurements of the absolute density of standard seawater and many relative measurements (using the Anton Paar equipment) of standard seawater. Several audience members noted that they also found Anton Paar measurements of standard seawater resulted in a negative salinity anomaly.

13.6 Chinese Seawater Standard (by Y. Li)
The speaker presented the NCOSM institute and its certification process. NCOSM is a government-run marine measurements institute in China. They recently carried out a JCOMM salinity intercomparison project. NCOSM also creates Chinese Standard Seawater. Y. Li gave an overview of its comparison with IAPSO Standard Seawater.

13.7 Salinity anomalies in arctic rivers and hydrothermal vents (by Rich Pawlowicz)
The speaker presented salinity measurements employing both density-based and conductivity-based measurement techniques. The differences between the two approaches were found to depend on the chemical composition of the sampled water (open ocean, near rives, near sea-ice, near hydrothermal vents). Studies on arctic rivers were carried out in summer 2015 as a part of the GEOTRACES program. Many rivers were reported to be "unconductive". The modeling of the salinity anomaly was found to perform quite well with a slight tendency for overprediction. The speaker strongly suggested that issues with Anton Paar measurements be resolved. Also, the North Pacific was reported to be a region of the largest salinity anomalies ("Line P" region). An intercomparison between TEOS-10, a semi-empirical model of R. Pawlowicz and measurements of salinity anomalies in this region revealed systematic differences between TEOS-10 and the semi-empirical model on one side and the measurements on the other side. Similar analysis has been performed in the Southern Pacific ("P18" region). The next steps are the repeat of line P measurements (done in June 2016) and P18 measurements (November 2016). A question of interest is to figure out, whether there is a sample handling problem or the observed effects are of physical origin. The speaker required to replicate measurememtns in another lab. There are interesting effects but artifacts must be safely excluded by further analyses (ongoing).

13.8 Salinity anomalies in the Baltic (by S. Weinreben)
The speaker reported on a decade worth of measurements of salinity anomalies in the Baltic Sea. No trend was found over time. He also noted a possible offset in measurements with the Anton Paar device. Comments by R. Pawlowicz noted that his model predictions of anomalies in the Baltic might compare well with the speakers measurements.

14. Chair: Rich Pawlowicz
14.1 Task group report on a guideline for the electrical conductivity of seawater (by Rich Pawlowicz)
The question of interest is how to link electrical conductivity C/(S/m) to salinity SA/(g/kg). It is known how to do it, but there is no reference document. The speaker stated the need for a guideline on conductivity of seawater with a comprehensive uncertainty analysis. The definition is given in the form of the conductivity formula with independent variables SA, t90, p, and salinity anomaly. The final solution is presented in the form SA = f(C, t90, p, salinity anomaly). There is a complicated calculational procedure with a number of intermediate variables (taking into account the structure of available primary data). An

estimation of the total uncertainty has been performed. Next steps include the finalization of the publication, the developmen of an IAPWS document, and the establishment of a task group. Items of cooperation with CCQM/BIPM have to be specified. R. Feistel noted that a new guideline plus a best practise measurements document are reqired! An IAPWS subgroup (members: Rich Pawlowicz, Rainer Feistel, Steffan Seitz, Trevor McDougall) is ordered to continue.

14.2 Task report on a supplementary release for a simplified density equation (by Rich Pawlowicz)
The report was about a supplementary release for a simplified density equation (rho=f(SA,CT,0), not yet documented). The problem is the use of CT as independent variable (CT=Conservative Temperature for oceanography, defined in TEOS-10, CT=f(T,p,SA)), which might not be used by non-oceanographers. Hence, we should not follow this path further, because an additional equation for CT is required. Recommendation that the task group should be disbanded.

14.3 Advisory note on IAPWS documents contributing to TEOS-10 (by Rainer Feistel)
The speaker presented an advisory note on IAPWS documents contributing to TEOS-10, draft version from 02 September 2016. Dan Friend: After editorial comments it should be adopted.
Recommendation to include an overview picture on the fundamental thermodynamic potentials.
For the editorial committee:
Hyperlinks to IAPWS documents. Re-numbering according to new IAPWS annotation standard.
The cited nine IAPWS documents should be maintained at the IAPWS website.
Formal enumbering of items should be revised.
Editorial committee: Allan Harvey, Jeff Cooper, A. Cook(?)

14.4 Recommendation for adoption (by vote)

15.1 Report of the task group on the use of covariances in IAPWS work (by Rainer Feistel).

The speaker identified several problems in the widely employed uncertainty analysis of empirical correlation equations. The IAPWS uncertainty analysis is also insufficient so far! A list of deficiencies has been presented (e.g. not providing covariances of the regression coefficients, ignoring statistical and cross-relation effects, analysis only partially relying on GUM recommendations.)

Basis: Feistel et al. (2016), discussion paper on uncertainty analysis.

Step 1: covariance progagation; Step 2: covariance of prediction.

Conclusions from a simple example IAPWS-95 Parameter correlation-coefficient matrix; application of the calculus to the IAPWS 2015 Eqs. for the second and third virial coefficients Bww(T), Cwww(T). The GLS uncertainty propagation method underestimates the uncertainty. The basis information of the new method is the covariance matrix. It should be mandatorily reported by experimentators (e.g. in a digital supplement) !!!

Items of the discussion: mathematics o.k., but provision of the covariance matrix is the problem; How to incorporate systematic errors in the calculus (very important)? Practical problems to fulfil/provide the covariance matrix from the experiments. Dan Friend: What can be recommended?

The are still several unanswered question. The task group should continue to work over the years! Application to the next revision of virial coefficients. Continue and check this within framework of internal use (TPWS working group). Recommendation within this working group to provide parameter covariance for new correlation equations to continue with this interesting task.

19.1 For EC: proposal for funding increase for cooperation with Maryland university
D. Friend = Gibbs award representative for TPWS
Rich Pawlowicz = Gibbs award representative for SCWS

Ingo Weber = Gibbs award representative for IRS

20. Membership
Withdrawn from SCSW: P. Spitzer (retired).

21. Contribution to press release
22. Preparation of the formal motion to the EC
It was approved that the chairman should do this.

PCAS WG Minutes

Dresden, Germany, 11-16 September, 2016

Present:
Andre Anderko (Chair) aanderko@olisystems.com
Masaru Nakahara nakahara@scl.kyoto-u.ac.jp
Vladimir Majer vladimir.majer@tul.cz

Andre Anderko opened the meeting. The agenda was approved without any additions. Masaru Nakahara was appointed clerk of minutes.

Minutes of the 2015 meeting were approved.

A round-table discussion of scientific work of the attendees was held. Andre Anderko described the work at OLI Systems on the aqueous solution chemistry of rare-earth elements, the properties of neutralizing amines and amine hydrochlorides, solution chemistry of actinides and thermodynamics of sodium phosphates, silicates and scale forming minerals. Vladimir Majer described his research on the solubility of gases in water and aqueous salt solutions. Masaru Nakahara reviewed his studies of self-diffusion coefficients of water using NMR over a wide range of thermodynamic conditions. Further, he described his work on the development of clean hydrogen fuel with formic acid used for chemical hydrogen storage.

The possibility of issuing ICRNs was discussed and no proposals were made.

PCAS Workshop (Monday)

The following presentation was made in the PCAS workshop:

Solubility of H_2S in NaCl(aq) over a wide range of temperatures and pressures: experimental data and correlation scheme (V. Majer)

In a discussion, it was indicated that this work could serve as a basis for a guideline.

PCC/PCAS Joint Workshop (Tuesday)

The following presentations were made:

Electrochemical corrosion potential monitoring in BWRs (Y. Wada)

Modeling actinide solution chemistry: Thermodynamic fundamentals for nuclear power industry (P. Wang and A. Anderko)

Update on geothermal chemistry (D. Addison)

TPWS/PCAS Joint Workshop (Thursday)

The following presentations were made:

Progress toward improved ideal-gas properties of ordinary and heavy water (J. Hrubý)

In discussion, it was indicated that the deviations from the previously accepted values (JANAF) are significant for heavy water.

Report of task group on isotopic fractionation (R. Feistel, A. Harvey, J. Hrubý, K. Maier)

Consensus has been reached that this task group should be kept inactive. Importance of fractionation anomalies in seawater has been indicated. J. Hruby raised the question of what to do with the report. Tentatively, it has been recommended to keep it internal to IAPWS.

Progress in modeling gas hydrates relevant for CCS using reference equations of state and extension of the model for mixed hydrates (S. Hielscher, A. Jäger, V. Vinš, R. Span, J. Hrubý, C. Breitkopf)

Carbon today and hydrogen in the future for chemical energy (M. Nakahara)

Rich Pawlowicz presented a request from ISO to IAPWS to assist in the development of a density model for produced water. A joint TPWS-PCAS task group has been formed to address this question, with R. Pawlowicz, A. Harvey, R. Feistel, and A. Anderko as members.

Guidelines

The following two guidelines have been discussed:

(1) Self-diffusion in high-temperature and supercritical water over wide density ranges by Masaru Nakahara and Ken Yoshida. The experimental work has been already published. It is planned to prepare a draft for the 2017 Meeting.
(2) Solubility of H_2S in water and aqueous solutions of NaCl and $CaCl_2$ by Vladimir Majer. Both the experimental work and the model have been published. Work on the guideline remains to be initiated.

Additionally, the following possible guidelines remain under consideration but no recent progress has been reported:

- Amine properties (James Bellows)
- Thermodynamics of hydration of gases and organic solutes (Josef Sedlbauer and Vladimir Majer)

Miscellaneous

Andre Anderko was nominated to be the PCAS representative for the Gibbs Award Committee.

IAPWS: Power Cycle Chemistry (PCC) Working Group

Minutes of IAPWS PCC WG Meetings

Location: Dresden, Germany, September 12 - 15, 2016
Chair: Michael Rziha

List of Abbreviations

EC	Executive Committee
ICRN	IAPWS certified research need
ICPWS	International Conference on the Properties of Water and Steam
PCAS	Physical Chemistry of Aqueous Solutions
PCC	Power Cycle Chemistry
TGD	Technical Guidance Document
WG	Working Group

Monday 12 September 2016

Power Cycle Chemistry (PCC) Working Group Meeting

Rziha welcomed participants, particularly new attendees from China, Egypt and Turkey.

1. Agenda

Amendments / Adoption of Agenda

The presentation by Addison on updates to the Corrosion Product Technical Guidance Document (TGD) for flexible plant was moved to Thursday 15 September to allow time for the sub-task group to meet during the IAPWS week.

It was requested that all presentations are listed in the meeting minutes as they are part of the formal proceedings that need to be reported by participants.

Action: Rziha to ensure that presentations are listed in the meeting minutes.

The IAPWS Executive Committee (EC) requested an update on ICRN #29 Coolant Sampling.

The agenda was otherwise adopted.

Week programme: Meetings, Joint Workshops and Task Groups

Rziha described the programme for the PCC WG meetings.

2. Appointment of Clerk of Minutes

P. McCann was appointed.

3. Approval of Minutes of PCC WG in Stockholm, 2015

The minutes from the Stockholm meeting were approved with no changes.

4. Progress Reports 2015/2016 and Future PCC Activities

Review of Actions from Last PCC WG Meeting

Updates to be provided on the following activities during the PCC meeting:

- Finalisation of TGDs on Application of Film Forming Amines in Fossil, Combined Cycle, and Biomass Power Plants and on HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemical Clean (Dooley).
- The corrosion product sampling campaign lead by SIAPWS (Thomsen).
- Geothermal power plant chemistry (Addison). The presentation will also act as the white paper as it summarises the findings from extensive discussions.

ICRN on Amines (Bellows): There is a separate PCAS agenda item on decomposition of acetic acid.

ICRN #26 Aluminium: No developments since the 2015 meeting.

Rziha noted increased international acceptance of the IAPWS TGDs during his work activities.

International Collaboration

There were no new proposals from PCC WG members for IAPWS international collaboration projects.

Cook/Addison proposed to request the IAPWS EC to extend timescales for their international collaboration project (see Tuesday 13th September, Section 3). Dooley explained that no formal EC approval was required as no additional budget is being requested.

Other Business

Rziha highlighted the IAPWS International Conference on Film Forming Amines and Products to be held in Lucerne, Switzerland on April 4-6 2017. Paper copies of the flyer were available and can also be downloaded from http://www.scpws.ch/scpws--en.html.

5. IAPWS TGDs – Status and Future Development

Draft TGDs for EC Submission

The PCC WG approved the submission of the following two TGDs to the EC for issue:

1. HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemical Clean

2. Application of Film Forming Amines in Fossil, Combined Cycle, and Biomass Power Plants

Action: Rziha to request EC approval for issue at the meeting on Friday 17 September.

Dooley noted that both TGDs have been reviewed extensively by the PCC WG, National Committees and by the Editorial Committee. The film forming amine (FFA) TGD involved most of the major chemical, boiler, HRSG and steam turbine suppliers worldwide. It was also noted that the FFA TGD was targeted at fossil, combined cycle and biomass plants only; nuclear plants need to consider separately.

Demineralised Water Integrity TGD
The TGD content has been drafted by Joy. The sub-task group (Joy [represented by McInnes], McCann, Buecher, Bellows, Hirano and Rziha) will meet during the week to discuss writing responsibilities and schedule. Khalifa, Shinotsuka and Ichihara also joined the task group.

Update from Existing TGD Sub-Task Groups

Monitoring corrosion products in cycling and two-shifting plants: A white paper is being developed by the sub-task group (Addison lead); the findings from the SIAPWS collaborative testing programme will be presented on Tuesday 13 September.

Instrumentation: A comparison of different methods for measuring Degassed Conductivity After Cation Exchange (DCACE) will be presented by Lendi (see Section 7).

Geothermal power plant chemistry: See Addison presentation, Tuesday 13 September 2016.

Future Developments

FFA TGD for Nuclear Plants: Cook has taken over from Uchida as chair of the Nuclear sub-committee. There is high interest in the use of FFAs in nuclear steam generators. The sub-committee will meet during the IAPWS week to discuss. Sub-committee members for the FFA TGD are: Lister, Jansen, Ichihara, Hirano, de Bache and Wada. The nuclear chemistry conference in Brighton, UK in September 2016 may also be an opportunity to seek participants.

Film Forming Products: Amendment of the FFA TGD for film-forming products that are not amines was discussed. The draft FFA TGD was considered suitable as an application document, though not as a scientific document for these products. No current action was proposed.

Air In-Leakage: The loss of efficiency and heat exchange performance due to air in-leakage is viewed as being poorly understood. A new sub-task groups was proposed, consisting of: Carvalho (chair), Dooley, Rziha, Nielsen and Thomsen.

Practical Experience: Addison presented on Practical Experience with the Application of IAPWS TGDs

6. Presentations

The following presentations were given:

- P. McCann: Experience with the Application of Film Forming Amines at the Uniper UK Connah's Quay CCGT Power Plant

- D. Lister: Studies on Two-Phase FAC; Modelling and Effects of Amine Breakdown Products

- F. Dyachenko: Use of FFAP at HRSG Power Plants in Russia
- T. Petrova: Use of ODA at Russian Power Plants
- S. Vidojkovic: Behaviour of Film Forming Amines in Water/Steam Cycle of Power Generating Units

7. PCC Task Group Meetings on TGDs

Dooley presented an overview of the new TGD on "HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemical Clean"

Demineralised Water Integrity sub-task group: McInnes provided an initial plan for drafting and timescales with section responsibilities.

Instrumentation sub-task group: Lendi presented on "Measurement of Degassed Conductivity After Cation Exchange - Additional Presentation on Different Measurement Methods". The key conclusion was that no specific degassing method needs to be specified as the measurement is only used for trending purposes. Information and recommendations could be used to update Steam Purity and Instrumentation TGDs, noting that the recent amendments to these TGDs for fast-starting plants included initial comments. The sub-task group was asked to put together a white paper for the 2017 meeting. To ensure commercial impartiality, the sub-task group needs to ensure that the white paper has input from all instrument manufacturers. Buecher from MT is to join the sub-task group.

Action F-U Leidich: The sub-task group is to prepare a white paper for the 2017 IAPWS meeting, to be circulated in advance to the PCC WG. The white paper is to have input from all instrument manufacturers.

Tuesday 13 September 2016

Power Cycle Chemistry (PCC) Working Group Meeting

1. Copies of Presentations

Rziha noted that presentations from the PPC WG proceedings will be made available to PCC WG members in PDF form on the Opal website.

Action Rziha: Presentations to be uploaded in PDF form onto the Opal website.

2. PCC Topics for ICPWS17

For the 17th International Conference on the Properties of Water and Steam (ICPWS17), the following topics were suggested for the PCC symposia:

1. IAPWS TGDs (Session organiser Dooley);
2. Water re-use and savings at power plant, e.g. grey water treatment, flue gas condensate (Organiser Thomsen);
3. Geothermal power plant chemistry (encouraging previous attendees from Moscow from Japan, Russia, NZ) (Organiser Addison);
4. Nuclear power plant chemistry (Organiser Cook);
5. Conventional and combined cycle power plant chemistry (Organiser Rziha);
6. Film forming amines / film forming products (Organiser Lister).

Action Rziha: Pass these topics onto the ICPWS17 organising committee.

3. Presentations

The following presentations were given:

K. Thomsen: SIAPWS Water Chemistry Network

K. Thomsen: Data from Corrosion Product Monitoring Measurements – Results of a Preliminary Test of Sampling Uncertainty

N. Ishihara: Water Chemistry Management Practices and Sampling Method of Japanese PWR Plants. It was noted that the sampling guidance presented may be used in a new TGD from the nuclear sub-committee.

W. Cook / D. Addison: Progress Report and Preliminary Results from the International Collaboration Project on Boiler Corrosion with Mixed Contaminants. IAPWS funding has been used to support D. Addison travel for 3 off 2 week visits to the University of New Brunswick for project scoping and design, rig construction and initial test work. There is £4,272 remaining of the IAPWS budget that will be used to continue support from Addison into 2017. The first tests are expected to start in January 2017.

4. Changes in Membership & Election of Officers

<u>New PCC WG Members</u>

The following new PCC WG members were proposed and seconded:

- Moataz Khalifa; PGESCO (Rziha/Dooley)
- Luis Carvalho, ChemTreat (Rziha/Dooley)
- Dr Yoichi Wada, Hitachi Ltd. (Rziha/Dooley)
- Sho Shinotsuka, Mitsubishi Hitachi (Rziha/Dooley)
- Dr Andreas Wecker, VGB (Rziha/Dooley)

- Monika Nielsen, Dong Energy (Rziha/Thomsen)
- Utku Kerem Gulcek, Enerjisa (McCann/Rziha)
- Mike Sparrey (Rziha/McCann).

Action Rziha: Submit the approved nominations to the IAPWS EC during the meeting on Friday 16 September.

Election of Officers

The terms of IAPWS WG chairs generally last for around 5 years. Rziha has served as PCC WG chair for 4 years, but was willing to continue for a further 3 - 4 years. The WG agreed with this proposal.

PCC/PCAS Joint WG Meeting and Workshop

The workshop consisted of the following presentations:

Y. Wada: Electrochemical Corrosion Potential (ECP) Monitoring in Boiling Water Reactors

A. Anderko: Modelling Actinide Solution Chemistry: Thermodynamic Fundamentals for Nuclear Power Industry

D. Addison: Update on Geothermal Chemistry. This presentation was effectively the white paper for Geothermal chemistry. The sub-task group is close to being able to produce a guideline. It is intended to update the geothermal section in the Steam Purity TGD and write ICRNs for missing knowledge. The sub-task group is aiming for the updates to be made in time for all reviews and approvals to be completed to allow formal approval at the IAPWS 2017 meeting.

PCC Workshop / WG Task Group Meetings

Iron Monitoring and Corrosion Product Sampling Sub-Task Group: The white paper will include the findings from the SIAPWS sampling programme. A key issue for benchmarking will be what are achievable values for different plants – there is an experience base for normal plant operation, but nothing available for flexible plant at present.

Nuclear Sub-Committee: The sub-committee will consider developing two TGDs; (1) nuclear power plant specific application of film forming amines / film forming products and (2) sampling and instrumentation. It is likely that only one TGD will initially be developed. The sub-task group consists of: Lister, de Bache, Wagner, Petrova.

Geothermal Sub-Task Group: International consensus is required for the final draft of the TGD, including Japan, Russia, etc. Much work has been done in New Zealand and international contacts are already well known. Luis Carvalho to join the sub-task group.

Meetings are planned of the Air In-Leakage and Demineralised Water Integrity sub-task groups.

Thursday 15 September 2016

Power Cycle Chemistry (PCC) Working Group Meeting

1. Presentations

The following presentations were given:

- J. Jensen: Water Chemistry Issues when Constructing a New Add-On Drum Boiler to an Existing Ultra-Supercritical Boiler/Turbine
- J. Jensen: Flue Gas Condensation – Possible Optimizations and Makeup Water Production
- H. Hirano: Overview of the Revision of JIS B 8223 "Water Conditioning for Boiler Feed Water and Boiler Water"
- S. Shinotsuka: High- AVT(LO) Water Treatment Application to Combined Cycle Plant
- D. Addison: Update on Iron Monitoring and Corrosion Product Sampling. This presentation described the plans from the TGD sub-task group to develop current guidance and to address knowledge gaps.
- B. Dooley: Plants with Aluminium Cooling Towers and Jet Condensers
- L. Daal: Applying Film-Forming Amines and Need for a Guidance Document from an Independent View
- L. Daal: Water Savings for Coal Fired Power Plants – Results of a Literature Search and Operator Opinions
- L. Daal: Global Experience Optimizing Cooling Water Systems Through Pulse-Chlorination

1. ICRNs – Review and Possible New Additions

- ICRN #22 Steam Turbine Phase Transition Zone Chemistry: The ICRN expired in 2015. Rziha proposed that the ICRN should be updated for 2 years on the recommendation of the author Stasny. This was agreed and Rziha will request the extension at the EC meeting. The contact details require updating. Rziha will manage this with the EC Editorial Committee.

  Action Rziha: Submit the ICRN for approval at the EC meeting on Friday 16 September. Update the contacts that are listed with the Editorial Committee.

- ICRN #29 Sampling: The final version has been received by Rziha from Lister. Rziha will present the final version to the EC for approval.

  Action Rziha: Submit the ICRN for approval at the EC meeting on Friday 16 September.

- ICRN #26 Aluminium: The ICRN now remains active to June 2019. Rziha proposed preparing a closing statement for the Prague ICPWS meeting in 2018 to include new information that is now available. There was agreed by the WG.

- There were no proposals for new ICRNs.

2. Discussion of Future PCC Activities and Task Groups

The discussions of the TGD sub-task groups were reported back as follows:

- Corrosion Product Monitoring sub-task group: Proposals were presented earlier by Addison.
- Nuclear Sub-Committee: A TGD on FFAs was discussed. There was consensus that there may be different effects compared to fossil plants. The first step will be to prepare a white paper comparing differences to fossil.
- Demineralised Water Integrity sub-task group: The contents list proposed by Joy was agreed. The next step will be to agree section authors.
- Geothermal sub-task group: See previous presentation by Addison.
- Rziha noted that new ICRNs can be proposed and drafted at any time.
- Air In-Leakage sub-task group: A white paper will be produced and the need for a TGD considered.
- Instrument sub-task group and Degassed Conductivity measurement: Following the earlier presentation, Lendi and the sub-task group will produce a summary document for PCC to review to include any recommendations for amendments to the Instrumentation TGD.
- Dyachenko asked about a TGD on preservation. Rziha commented that a new guidance document was available from the VGB that covered all plant areas, not just the water-steam cycle. The German version has been released. It will be available in English later in 2016. It was decided to review the need for an IAPWS document at the 2017 meeting.

  Action Rziha: Include as an agenda item at 2017 meeting.

- A white paper on Condensate Polishing Plant was suggested by Khalifa. This would have to be written in a neutral technical matter and it must not be a commercial discussion. Khalifa will provide a paper at the 2017 meeting to include any IAPWS product that could assist in this technical area.

  Action Khalifa*: Provide paper at 2017 meeting.*

3. Gibbs Award

This is an award for a senior researcher in areas of interest to IAPWS. Any nominations from PCC WG members need to be sent to Rziha by May 2017.

4. PCC Public Relations

The following were agreed as PCC WG highlights for the IAPWS meeting press release:

- Two new TGDs – HRSG HP Evaporator and FFAs;
- Two more TGDs in preparation: Demineralised water plant integrity and corrosion product sampling for cycling plants;
- White paper to be developed for air in-leakage;
- Further steps in data collection and knowledge on aluminium as per ICRN#26.

A summary of PCC WG proceedings will be produced for the PowerPlant Chemistry journal by Rziha.

Action Rziha: Produce article for the PowerPlant Chemistry journal.

Participants were asked to consider including the IAPWS logo on future conferences related to power plant chemistry to increase awareness of the organisation. Members can contact B. Dooley about this.

5. Dates and venue for 2017 Meeting

The 2017 IAPWS meeting will be in Kyoto, Japan, on August 27 – September 1.

The 17th ICPWS will be held in Prague on 2 -7 September 2018. PCC topic suggestions have been passed to the Czech organising committee by Rziha.

6. Miscellaneous and Adjournment

Rziha was thanked for his work in chairing the meetings at Dresden. The meeting was then adjourned.

Press Release:

International Association for the Properties of Water and Steam

2016 ANNUAL MEETING, DRESDEN, GERMANY

Continuing a series of conferences that began in 1929 in London, 90 scientists and engineers from 18 different countries, along with 11 accompanying persons, attended the annual meeting of the International Association for the Properties of Water and Steam (IAPWS). The German National Committee of IAPWS hosted the meeting between 11th and 16th September 2016 at the Steigenberger Hotel de Saxe in Dresden, Germany. The highlights of the IAPWS working group sessions and other proceedings of the Executive Committee are summarized in this release.

The primary purpose of the annual IAPWS meeting is to connect researchers and scientists with the engineers who use their information. This information exchange provides the researchers with guidance on topical problems within industry and provides the engineers with the latest research results. Areas of application include power cycle chemistry, high temperature aqueous technologies applicable to steam cycles and fuel cells, the use of high temperature water and supercritical steam in chemical and metallurgical processes, supercritical synthesis of new materials and destruction of toxic wastes, hydrothermal geochemistry, hydrometallurgy, oceanography, power cycles with CO_2 capture and storage systems and combined heat and power systems including district heating.

IAPWS produces releases and guidelines on the recommended scientific formulations for physical and chemical properties of water in its various forms as well as technical guidance documents that are the concerted opinion of IAPWS members on best operating practices for power plant chemistry. IAPWS also documents certified research needs that represent the opinion of experts in their respective fields that research on a particular subject is greatly needed to fill a current gap in knowledge. All of this information is freely available and can be found on the IAPWS website at **www.iapws.org**.

The Working Group on Thermophysical Properties of Water and Steam (TPWS) discussed interesting new results on thermophysical properties of metastable liquid water – water cooled below the freezing temperature. Some of this work has led to a new IAPWS Guideline on properties in this region, and related work will improve the description of the melting curves of ice, especially at high pressures. New data, most of it obtained in projects involving TPWS

members, is leading to improved formulations for the surface tension of water and for the thermodynamic properties of heavy water; both are expected to be completed in 2017.

The Industrial Requirements and Solutions (IRS) working group discussed reports on successful applications of the "IAPWS Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL)" released last year. The working group also discussed further areas of interest to industry besides wet steam properties of practical interest (direct wetness measurement, guidance on transport properties in wet steam). New topics in the areas of freezing phenomena, properties of slurry ice, etc. were identified and detailed requirements for these areas will be examined in the upcoming year.

The Subcommittee on Seawater continued working towards the traceability of marine measurements, especially for salinity. A number of talks were presented on salinity and density measurements, and it was resolved that an international coalition should work towards identifying outstanding issues with density measurements in Standard Seawater. Work is also actively proceeding to define the electrical conductivity of seawater.

In the meetings of the Power Cycle Chemistry (PCC) working group, two new technical guidance documents (TGDs) were approved for release: "Application of Film Forming Amines in Fossil, Combined Cycle and Biomass Plants" and "HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemical Clean". Additionally, the PCC working group discussed development of new TGDs involving demineralized water requirements and the use of film forming amines in nuclear plants, and are developing several whitepapers including corrosion product sampling for plants on flexible operation and minimizing air in-leakage into steam-water cycles. PCC also identified a significant step forward in the understanding of the behaviour of Al in steam cycle circuits.

IAPWS produces Certified Research Needs (ICRNs) as guidance for funding agencies and as an aid to people doing research in defining important research. To date, these have covered a variety of areas related to the properties of water and steam, seawater and the chemistry of power plants. A list of currently active ICRNs and closing statements on the progress made for those that have expired can be found on the IAPWS website.

A symposium entitled "Steam, Water and Aqueous Mixtures in Energy and Process Engineering" was held on Wednesday 14th September 2016**.** The symposium included several presentations focused on transformational change in the energy sector to meet global CO_2 reduction targets, thermodynamic properties of water, water-CO_2 mixtures, water-alcohol mixtures and the use of water as a refrigerant. The IAPWS Helmholtz award lecture is traditionally the cornerstone of the IAPWS Symposium. This year's award winner was Dr. Frédéric Caupin from the University of Lyon, France. His work and the topic of his presentation surround the Equation of State of metastable water at negative pressure. Also presenting at this year's Symposium was Dr. Vincent Holten, the 2015 Helmholtz award winner who was unable to attend the meeting last year. The IAPWS Helmholtz award is given annually to developing or early career scientists and engineers who are working in a field of interest to IAPWS. It includes an opportunity to attend the annual IAPWS meeting and to present the Helmholtz Award lecture.

The IAPWS Honorary Fellow award was conferred during the meeting banquet, which was held in the ballroom of the Hilton-Dresden Hotel. The Honorary Fellow award is given in recognition of many years of contribution to the Association. At the 2016 meeting, the recipient of the IAPWS Honorary Fellow award was Dr. Allan Harvey from the National Institute of Standards and Technology in the United States in recognition for long-standing efforts in formulating and improving IAPWS releases as member and Chair of the Working Group Thermophysical Properties of Water and Steam, Chair of the Editorial Committee and, for outstanding scientific work in the field of fluids and aqueous systems, including ab-initio calculation of molecular interactions.

This year, IAPWS welcomed New Zealand as a new full member of the association and formally approved Egypt as an associate member. IAPWS welcomes scientists and engineers with interest in the thermophysical properties of water, steam, and aqueous systems and in the application of such information to industrial uses. The next IAPWS meeting will be in Kyoto, Japan from 27th August – 1st September 2017. Preparations are also underway for the 17th International Conference on the Properties of Water and Steam (ICPWS) that will be held between 2nd – 7th September, 2018 in Prague, Czech Republic. Further information on meetings can be found at the IAPWS website (www.iapws.org) as it becomes available.

People interested in IAPWS documents and activities should contact the Chairs of their IAPWS National Committee (see the IAPWS website for contact details) or contact the IAPWS Executive Secretary, Dr. R. Barry Dooley, bdooley@structint.com. People do not need to be citizens or residents of member countries to participate in IAPWS activities.

Group photo of the participants of the 2016 IAPWS meeting, Dresden, Germany.

Argentina and Brazil Bi-National Committee
(Associate Member)

International Association for the Properties of Water and Steam

REPORT on IAPWS related activities - June 2016

Institutions participating in the research of thermo-physical properties and chemical processes:

- Comisión Nacional de Energía Atómica, Argentina
- Energetic and Nuclear Research Institute (IPEN) of the Brazilian Nuclear Energy Commission (CNEN)

Activities of Argentina Group:

A. At INQUIMAE (University of Buenos Aires) and the Department of Physics of Condensed Matter (CNEA), Dr. Corti's group is working on:
- Properties of the ice-vacuum interphase under supercooled conditions, using theoretical and experimental (AFM) techniques (in collaboration with Dr. Igal Szleifer group at Northwestern University).
- Transport and thermodynamics properties of aqueous ionic and non-ionics solutions in nano and mesoporous materials (silica and carbon).
- Development and characterization of materials (catalysts and membranes) for electrolytic splitting of hydrogen.
- Phase transitions in LiCl supercooled aqueous solutions induced by high pressure (in collaboration with Dr. Thomas Loerting group at Innsbruck University)

Activities of Brazilian Group:

A. Development of a Package to implement IAPWS-95 in "R"

The objective of this project is to develop and implement a new "R" package to supply water and steam properties, allowing easier analysis of experimental data for scientists and engineers that work with thermal and hydraulic water experiments and make use of "R".

"R" is a language and environment for statistical computing and graphics developed by "The R Foundation for Statistical Computing", from where we took the main information presented below (https://www.r-project.org/foundation/).

Project Tasks

1. Programming and compilation of a dynamic link library for the IAPWS-95 properties;

2. Development of the "R" Package called "waterPropertiesIAPWS95";

3. Implementation of this package at CRAN (*The Comprehensive R Archive Network*)

The activities of this project had being started by the Brazilian representative. The first task is almost complete and more than 80 functions for properties calculation based on IAPWS-95 are already working and tested in the "R" environment. New collaborators will be included in the project as it proceeds.

B. Starting activities to motivate Eletronuclear to give support to the Brazilian activities

Eletrobras Eletronuclear is a Brazilian company supplying electricity from nuclear energy. It is the Brazilian Nuclear Power Plants operator which controls two PWR Plants (Angra I and Angra II) and is the responsible for the construction of the third Nuclear Power Plant at Brazil, Angra III.

Dr. Leonam dos Santos Guimaraes from Eletronuclear will share the Brazilian representation with Prof. Dr. Benedito Dias Baptista Filho. With this new participation we may be able to held a future meeting of IAPWS at the City of Rio de Janeiro. He is an Executive Assistant to Eletronuclear CEO and Technical and Commercial Director of Amazonia Azul Tecnologias de Defesa S.A. (AMAZUL). He has a Doctoral Degree in Ocean Engineering on Naval Nuclear Propulsion and has around 30 years of experience in research, development, engineering, procurement and construction of naval and nuclear systems.

In a near future we will try to indicate a possible participant in the "Power Cycle Chemistry" area.

C. Study of Ionizing Radiation Effects on Nanofluids properties

A new research has just being started at IPEN with the main purpose of investigating the behavior of the thermal physical properties of nano-fluids during and after high doses of ionizing radiation influence. The fluid under investigation is light water with nano particles of Al2O3, TiO2, BeO, ZrO2.

Publications of Argentina Group:

- Pressure-induced transformations in aqueous LiCl solutions at 77 K. G. N. Ruiz, L. E. Bove, H. R. Corti, T. Loerting. Phys Chem. Chem. Phys. 16, 18553-18562 (2014).
- Diffusion-viscosity decoupling in supercooled glycerol aqueous solutions. J. A. Trejo González, M. P. Longinotti, H. R. Corti. J. Phys. Chem. B, 119, 257–262 (2015).
- Kinetics of the hydrogen evolution on nickel in alkaline solution by rotating disk electrode. E. A. Franceschini, G. I. Lacconi, H. R. Corti. Electrochim. Acta, 159, 210-218 (2015).
- Quasi liquid layer and surface melting of ice in contact with and AFM tip by molecular dynamics simulation. J. Gelman-Constantín, M. A. Carignano, H. R. Corti, I. Szleifer. J. Phys. Chem. C, 119, 27118–27124 (2015).
- Ni activation for H2 evolution reaction by spontaneous Ru deposition: a rotating disk electrode and impedance spectroscopy approach. E. A. Franceschini, G. I. Lacconi, H. R. Corti. Int. J. Hydrogen Energy, 41, 3326-3338 (2016).

- KOH-doped ABPBI membrane for alkaline water electrolysis: characterization and performance. L. A. Diaz, J. Hnát, N. Heredia, M. M. Bruno, F. A. Viva, M. Paidar, H. R. Corti, K. Bouzek, G. C. Abuin. J. Power Sources, 312, 128-136 (2016).

- Proton conductivity and water uptake of acid-doped ABPBI membranes prepared by low-temperature casting. L. A. Diaz, G. C Abuin, H. R. Corti. J. Electrochem. Soc., 163, F485-F491 (2016).

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IAPWS Canadian National Committee

Annual Report 2016

Submitted to IAPWS EC, Dresden, Germany, September 16, 2016

CNC Executive: *William Cook (Chair); Derek Lister; Peter Tremaine; Melonie Myszczyszyn; Rich Pawlowicz; Steve McGee (CANDU Owners Group Representative, Treasurer).*

1. Canadian National Committee: Dues for the Canadian National Committee (CNC) of IAPWS are supported by the National Research Council of Canada (NRC). 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 an initial five-year term, including travel support for the academic members of the CNC. In December 2012, COG agreed to another five-year term as the CNC's industrial sponsor (2013-2017). An agreement with COG and the NRC for a third five-year term as the CNC's sponsor was signed in June 2016 providing continued involvement with IAPWS and the CNC through 21st June 2021. Thanks to Steve McGee for ensuring the renewal proceeded smoothly.

After two years acting as the IAPWS Vice President, Dr. Dave Guzonas transitioned to the role of IAPWS President for 2015-2016. Due to personal reasons, in March 2016, Dave Guzonas retired from the Canadian Nuclear Laboratories and as a result, resigned from his position as President of IAPWS. The CNC wishes Dave well in his retirement. The CNC is currently engaging COG and CNL to find a replacement for Dave Guzonas on our committee so that CNL and the Canadian nuclear industry's interests continue to be well represented within IAPWS.

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) wrapped up in March 2016. Seven water chemistry projects covering two main themes were investigated: a) corrosion product transport and deposition, and b) water radiolysis. The program developed chemistry control strategies for the SCWR as well as recommending realistic chemistry conditions for corrosion testing for materials selection. The program also funded eight projects examining materials degradation phenomena (e.g., corrosion, stress corrosion cracking, creep, ageing) at temperatures up to 800 ºC. The chemistry program was co-ordinated by D. Guzonas (CNL). 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. F. X. University): Time-resolved investigations of metal oxide-water systems under conditions of extreme temperature, pressure and radiation.
P. Percival (Simon Fraser University) &: Reaction kinetics in SCW probed using muonium.
K. Ghandi (Mount Allison University)

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).

3. CNC Member Activities

3.1 Activities at the University of New Brunswick

Derek Lister

Heat exchanger fouling; the recirculating water loop built for studying deposit formation on heat-exchange surfaces has been refurbished with a new test section (including a simulated heat exchanger tube with a high heat-flux heater) and control system. It is currently being commissioned prior to looking at the effects of a film-forming amine (FFA) on boiling heat transfer and the concomitant deposition of colloidal magnetite. The forces between magnetite particles and submerged surfaces with and without FFA additions are being investigated with atomic-force microscopy (AFM) in collaboration with CNL.

Flow-accelerated corrosion (FAC); experiments on the effects of FFA on FAC are proceeding in two recirculating water loops. Under feedwater conditions at 140°C, a commercial product is being investigated for its efficiency in mitigating FAC with no pH additive, while under two-phase steam-water conditions at 200°C another commercial product is undergoing similar testing.

Modelling reactor primary circuit contamination; inserting FAC mechanisms and in-core effects into models for material transport has led to predictions of the transport of radioactive corrosion products in a CANDU primary coolant system. The next task modelling the development of radiation fields around critical components.

Developing a robust probe for measuring FAC in-situ in operating plant; three probes have been successively installed downstream of the boiler feed pump in a coal-fired power station. After analysis of the results from the first probe, refinements were made to the system before the second probe was installed. The third probe was recently installed and analysis of the results from the second is continuing.

Verifying the effects of dissolved iron on FAC; experiments injecting iron into a coolant stream by promoting FAC upstream of an in-situ FAC probe are complete. The measured effects have been successfully described in terms of UNB's mechanistic model.

Modelling FAC under two-phase conditions; UNB's mechanistic model has been adapted to describing FAC in steam-water mixtures by applying the single-phase mechanisms to the conditions in the liquid film on piping surfaces, using vapour-liquid distribution parameters of additives such as ammonia to obtain the liquid phase chemistry and using standard correlations for predicting quantities such as mass transfer coefficient and fluid shear stress at the wall. Preliminary trials have indicated good agreement with experimental results.

Measuring the effusion rate of hydrogen through steel; in a collaborative project with UNB's Centre for Nuclear Energy Research, the development of an in-situ probe (HEPro) for monitoring FAC by measuring the rate of effusion of corrosion hydrogen through pipe walls is being supported by investigating the details of hydrogen diffusion around the probe structure.

Electrochemical influences in FAC; an in-situ FAC probe in a high-temperature water loop is made the working electrode of a three-electrode system and the corrosion characteristics are separately investigated by electrochemical techniques.

Willy Cook

W. Cook has been acting as the Director of the Centre for Nuclear Energy Research (CNER), a research institute on UNB's campus. CNER has over two-decades of research / collaboration with the nuclear industry and has developed and patented online sensors for monitoring corrosion of plant piping in-situ. Additional field trials to show the utility of the sensors for nuclear power plants are currently in preparation. CNER is continuing to grow its consulting expertise and provides services to Canada's nuclear industry. The recommendation to formally appoint W. Cook as CNER's Director was made by the CNER Advisory Board in June 2016. The term will last four years.

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.

Hydrogen control in CANDU cooling systems is a project initiated in 2014 in conjunction with industrial collaborators. Current CANDUs have several nuclear auxiliary light water systems that are exposed to intense radiation fields. Suppression of water radiolysis and mitigation of hydrogen production in these systems using alternate oxygen scavaging chemical to hydrazine is the primary goal. The experimental program is in full operation with a Master's student working full time at the Chalk River Nuclear Laboratories. Preliminary results are indicating that corrosion processes on carbon steel can significantly affect the reaction kinetics and production from water radiolysis.

W. Cook and David Addison (Thermal Chemistry Inc. – New Zealand) were awarded an IAPWS International Collaboration project 2015. The focus of the project was to establish capabilities at UNB / CNER's laboratories to measure, electrochemically, the effects of mixed contaminants on boiler materials. D. Addison visited UNB / CNER on three occasions between Nov. 2015 and June 2016 and the test rig was designed and commissioned. Further funding for the project was secured from Thermal Chemistry and from Swan (thanks to David Addison and Lukas Staub).

3.2. Activities at the University of Guelph (Peter Tremaine)

Peter Tremaine was appointed to a newly created NSERC/UNENE Senior Industrial Research Chair in High Temperature Aqueous Chemistry in June 2016. The objective is to expand mission-oriented basic research and modelling expertise at Guelph in areas related to primary coolant chemistry, moderator chemistry, steam generator chemistry and nuclear waste management, and to recruit a tenure-track junior faculty member to address succession planning issues. In addition to UNENE, the industrial partners are the CANDU Owners Group, the Nuclear Waste Management Organization and the Electric Power Research Institute. The site visit took place in October, 2015, and the Chair was approved by NSERC on December 20, 2015, subject to receiving signed agreements from the four sponsoring organizations. Legal negotiations were completed in late May 2016.

Other current and recent projects include (i) Solvation and Equilibria of Ions and Organic Solutes in Water up to Near-Critical Conditions (ii) CANDU Nuclear Reactor Chemistry: D_2O Isotope Effects on Acid-base Ionization and Metal Hydrolysis (UNENE/NSREC CRD Grant), (iii) Generation IV Nuclear Reactor Chemistry: Ion Pairs and Complexes in Sub-critical and Supercritical Water (NRCan/AECL/ NSERC CRD Grants), (iv) Carbon Capture and Sequestration by Novel Phase-Separating Solvents (NSERC International Strategic Grant with University Blaise Pascal, France)

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

IAPWS-related activities continue to concentrate on investigations into the effect of chemical composition changes in seawater on its physical properties, and coordination of international activities in supporting and extending the seawater standard TEOS-10 through chairmanship of the Joint SCOR/IAPWS/IAPSO Committee on the Properties of Seawater (JCS).

Field measurements of "density anomaly": (1) Measurements of river anomalies were made in the Canadian Arctic Archipelago as part of a Canadian GEOTRACES rivers project (with H. Uchida and K. Brown) (2) Measurements were made (again) on the ocean "Line-P" section (run by the Canadian Department of Fisheries and Oceans) in the northeast Pacific, to try and understand and replicate some unusual features of interest.

A major milestone for JCS was the publication of 4 linked papers to the journal Metrologia. These papers discuss proposed plans for developing traceability of seawater salinity, salinity pH, and relative humidity to the International System of Units (SI); they are now (8 months after publication) among the most "downloaded" (or read) articles in that journal, with more than 10,000 downloads (Pawlowicz is an author or co-author on 3 of the 4).

3.4. CANDU Owner's Group (COG) Activities (Steve McGee)

COG is a not-for-profit corporation with voluntary funding from international CANDU-owning utilities and Canadian National Laboratories. The COG mission is to improve the performance of CANDU stations worldwide through member collaboration. COG Canadian R&D program members include Ontario Power Generation, Bruce Power Limited Partnership, New Brunswick Power and Canadian Nuclear Laboratories.

IAPWS CNC Workshop – October 2015

On October 19th, 2016 the CNC held a Workshop at the COG offices in Toronto with 16 attendees from both industry and academia. The following presentations were made:

Background on IAPWS and the CNC-IAPWS structure
Current IAPWS Working Groups and activities
Candu Owners Group (COG) – synergies between the nuclear and fossil industries
Value of Robustness in Water Plant Treatment, in Design, Operation, Monitoring and Maintenance
Challenges with Plant Layup During Flexible Operations
Summary of Current and Planned IAPWS Technical Guidance Documents
Coolant sampling in power generating systems
D_2O isotope effects on transport properties and ionization constants in high temperature water by AC conductivity
Water Challenges Associated with Hydraulic Fracturing
FAC in power generating circuits
IAPWS Initiative – Corrosion Product Sampling for Plants with Flexible Operation (discussion)
Round Table / Panel Discussion: Engaging Canadian Industry in IAPWS activities

CANDU Industry-IAPWS Engagement

The presentations "HEPro and its Use at PLGS" and "Extending Studies of FAC under Single-Phase Conditions to Two-Phase Steam Water Conditions" were made by Dr. William Cook and Dr. Derek Lister respectively, at the COG FAC Workshop in May 2016.

Dr. Peter Tremaine, Dr. William Cook and Dr. Derek Lister have participated in the COG R&D Chemistry Working Group meetings and have informed Working Group members of the research activities at the University of Guelph and the University of New Brunswick. IAPWS activities and their benefits have been presented to the COG Chemistry Working Group by Dr. Tremaine, Dr. Cook, Dr. Lister.

The COG R&D Chemistry Working Group has made a five-year commitment to fund the University of Guelph Industrial Research Chair in the field of "High Temperature Aqueous Chemistry" which was formally approved in May 2016. COG members are also funding the Collaborative Research and Development Grant "Chemistry and Corrosion in Nuclear and Conventional Power System Coolants" at the University of New Brunswick for the five year period (2014 – 2019). Plans are under development to formally incorporate university research programs with the COG industry Working Groups, which should further integrate and leverage the value of IAPWS activities with the COG R&D program.

CANDU Industry-Technology Implementation

There is ongoing research at Chalk River Laboratories to investigate the thermal resistances and fouling rates prior to and after the application of the Areva Film-Forming Amine. This project is to provide an independent technical basis for using Areva Film-Forming Amine during the upcoming CANDU station refurbishment outages. COG Joint Project 4494 "Qualification of Film Forming Amine (FFA) Preservation of Steam Generators" is underway to qualify the process for the participating CANDU stations. A presentation about implementing the Areva Film-Forming Amine process were made at the June 2015 CANDU Chemistry Workshop by Dennis Moghul (OPG) (Film Forming Amine Application for Darlington Refurbishment Lay-up Protection).

4. Activities Planned to Next ICPWS (2017/18)

The CNC activities over the next few years will continue the work that is currently ongoing, as described above. The supercritical water-cooled reactor project concluded Phase II in 2016 but may have more focused research beginning in Phase III, potentially beginning in 2017.

A IAPWS CNC workshop for Canadian industry and academic stakeholders is in the planning stages for Winter/Spring 2017. The goal would be to raise the profile of the Canadian National Committee and IAPWS activities with researchers in Canada doing complementary research within the fossil and HRSG community. A working topic is FAC in steam raising systems.

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 provided contacts with the CANDU community to support the work.

5. Select List of Publications

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2. R Feistel, R Wielgosz, S A Bell, M F Camões, J R Cooper, P Dexter, A G Dickson, P Fisicaro, A H Harvey, M Heinonen, O Hellmuth, H-J Kretzschmar, J W Lovell-Smith, T J McDougall, R Pawlowicz, P Ridout, S Seitz, P Spitzer, D Stoica and H Wolf: Metrological challenges for measurements of key

climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview. REVIEW PAPER. Metrologia, 53 (2016) R1–R11, doi:10.1088/0026-1394/53/1/R1

3. R Pawlowicz, R Feistel, T J McDougall, P Ridout, S Seitz, H Wolf: Metrological challenges for measurements of key climatological observables, Part 2: Oceanic salinity. REVIEW PAPER. Metrologia, 53 (2016) R12–R25, doi:10.1088/0026-1394/53/1/R12
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9. Swift, R. and Cook, W.G., *Validation of Constant Load C-ring Apex Stresses for SCC Testing in Supercritical Water*, accepted to Journal of Nuclear Engineering and Radiation Science, in press.
10. Steeves, G. and Cook, W.G., *Development of Kinetic Models for the Long-term Corrosion Behaviour of Candidate Alloys for the Canadian SCWR*, accepted to Journal of Nuclear Engineering and Radiation Science, in press.
11. Cook, W., Brown, G., Smith, B. and Stuart, C., *Evolution of Radiation Fields in the Point Lepreau CANDU Reactor Following Refurbishment*, accepted to Nuclear Plant Chemistry Conference (NPC 2016), Brighton, UK, October 2016 (accepted).
12. Stuart, C., Lee, J., Gardner, E. and Cook, W., *Steam Cycle Contamination and Remediation following the Refurbishment Outage at the Point Lepreau Generating Station*, accepted to Nuclear Plant Chemistry Conference (NPC 2016), Brighton, UK, October 2016 (accepted).
13. Lyons, J., Cook, W., Stuart, C. and Gardner, E., *Synergistic Effects Between Radiation Chemistry and Carbon Steel Corrosion in the Calandria Vault and End Shield Cooling System of a CANDU Reactor*, accepted to Nuclear Plant Chemistry Conference (NPC 2016), Brighton, UK, October 2016 (accepted).
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23. W. Zheng, D. Guzonas, K. Boyle, J. Li, S. Xu, Materials Assessment for the Canadian SCWR Core Concept, JOM, v 68, n 2, p 456-462, February 1, 2016.
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31. Lister, D.H., Weerakul, S. and Caravaggio, M. (2015). "Laboratory Tests on the Effects of Amines on FAC in Single-Phase and Two-Phase Flows". IAPWS 2015 Annual Meeting, Stockholm, Sweden. June 26-July 3.
32. Lister, D.H., Mohajery, K. and Uchida, S. (2015). "The Controlling Mechanism in FAC: Protective Oxide Dissolution or Fluid Flow". Ibid

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37. Santiwiparat, T. Rirksomboon, T., Steward, F.R., Lister, D.H. and Cook, W.G. (2016). “Modelling Hydrogen Permeation in a Hydrogen Effusion Probe for Monitoring Corrosion of Carbon Steel”. 36th Annual Conference of the Canadian Nuclear Society, Toronto, ON, June 19-22.

38. Mohajery, K., Liu, L., Lister, D.H. and Uchida, S. (2016). “Flow-Accelerated Corrosion in Two-phase Stem-Water Flows: Experiments and Modelling”. 20th International Conference on Water Chemistry of Nuclear Reactor System, UK. October 2-7

Report on IAPWS-related activities: May 2015 – May 2016

submitted by the

Czech National Committee for the Properties of Water and Steam (CZ NC PWS)
to the Executive Committee Meeting of 2016 IAPWS Meeting, Dresden, Germany, in September 2016

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Participating institutions

The following Czech Institutions participated in the research of thermophysical properties and chemical processes between May 2015 and May 2016:

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Czech Technical University in Prague ("CTU"), Faculty of Mechanical Engineering, Department of Fluid Mechanics and Thermodynamics, and Department of Power Engineering, Technická 4, CZ-166 07 Praha

Institute of Chemical Technology, Prague ("ICT"), Department of Power Engineering ("ICT-DPE") and Department of Physical Chemistry ("ICT-DPC"), Technická 5, CZ-166 28 Praha 6

University of West Bohemia ("UWB"), Faculty of Mechanical Engineering, Department of Power System Engineering, Univerzitní 8, CZ-306 14 Plzeň

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University of South Bohemia ("USB"), Faculty of Science, Branišovská 31A, CZ-370 05 České Budějovice

The founder of the CZNCPWS is the Czech Academy of Sciences.

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Board of CZ NC PWS for 2014-2017

Dr. J. Hrubý
Prof. R. Mareš
Dr. T. Němec
Prof. P. Šafařík
Prof. J. Šedlbauer

List of IAPWS-Related Activities

The project of IT CAS sponsored by the Ministry of Education, Youth and Sports of the Czech Republic has been the source of financial support for the international collaboration of CZNCPWS with IAPWS since 2016. The project support will end on 31/12/2017.

Dr. Hrubý and Dr.Vinš (IT CAS) and their collaborators from IT CAS continued their experimental investigation of surface tension of supercooled water [1,5,6,7] and density of supercooled water at elevated pressures [6,7]. In joint cooperation with the team of Prof. Roland Span form Ruhr-University Bochum they progressed in modeling of gas hydrates relevant to carbon capture and storage [3,4]. In addition, the vapor-liquid phase interface of water was studied using molecular dynamic simulations [2,7].

Prof. Mareš (UWB) and Dr. Kalová (USB) studied surface tension of water and water nanodroplets [8-9].

Dr. Němec (IT CAS) studied bubble nucleation in binary systems of liquid solvent and dissolved gas. His theoretically model enabled him to evaluate the influence of dissolved gas concentration in water on the process of bubble formation [10].

Assoc. Prof. Kolovratník (CTU) and Dr. Bartoš carried out pneumatic and optical measurements of a wet steam flow field upstream of the last stage of a nuclear power-station steam turbine. This unique measurement has produced useful new information for the manufacturer and operator of the steam turbine and valuable experimental data for phase transition modelling in wet steam flows [11].

Mr. Nový (DOOSAN ŠKODA POWER) and his collaborators studied the speed of sound in steam [12] and carried out numerical simulations of flow with condensation in nozzles based on homogeneous nucleation.

Dr. Sedlář (SIGMA) and his collaborators studied cavitation erosion in water pumps [13] and the problem of cavitation instabilities in hydrodynamic conditions [14-16].

The team of Prof. Šedlbauer investigated thermodynamic properties of H2S-H2O-NaCl solutions [17].

The team of Assoc. Prof. Hnědkovský (ICT-IPC) studied thermodynamic properties of aqueous solutes in water [18-25].

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[4] Vinš V., Jäger A., Hrubý J., Span R.: Hydrate Model for CCS Relevant Gases Compatible with Highly Accurate Equations of State I. Parameter Study and Model Fitting, 19th Symposium on Thermophysical Properties, Boulder, 2015.

[5] Vinš V., Hošek J., Hykl J., Hrubý J.: Surface Tension of Supercooled Water Down to – 22 °C Measured with a Horizontal Capillary Tube, 19th Symposium on Thermophysical Properties, Boulder, 2015.

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German National Committee to IAPWS

Research Activities on the Thermodynamic Properties of Water and Steam
Report "Research in Progress 2016"

Baltic Sea Research Institute, Warnemuende
Dr. Rainer Feistel

Projects

1. Development of a draft Advisory Note No. 6: "Relationship between Various IAPWS Documents and the International Thermodynamic Equation of Seawater – 2010 (TEOS-10)"
2. Preparation of a paper about Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air to be submitted to Int. J. Thermophys.
3. Preparation of a paper about unleashing empirical equations using nonlinear fitting & GUM tree calculator to be submitted to Int. J. Thermophys.
4. Preparation of a paper toward a fundamental definition on relative humidity to be submitted to Int. J. Thermophys.

Recent Publications

- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.:
  Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air.
  Int. J. Thermophys. (2016), in preparation.
- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.:
  Digital Supplement to "Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air".
  Int. J. Thermophys. (2016), in preparation.
- Lovell-Smith, J. W.; Saunders, P.; Feistel, R.:
  Unleashing empirical equations using nonlinear fitting & GUM tree calculator.
  Int. J. Thermophys. (2016), in preparation.
- Lovell-Smith, J. W.; Feistel, R.; (and others):
  Toward a fundamental definition on relative humidity.
  Int. J. Thermophys. (2016), in preparation.
- Feistel, R.; Lovell-Smith, J. W.; Saunders, P.; Seitz, S.:
  Uncertainty of Empirical Correlation Equations.
  Metrologia 53 (2016), pp. 1079-1090, doi: 10.1088/0026-1394/53/4/1079.
- Feistel, R.; Wielgosz, R.; Bell, S. A.; Camões, M. F.; Cooper, J. R.; Dexter, P.; Dickson, A. G.; Fisicaro, P.; Harvey, A. H.; Heinonen, M.; Hellmuth, O.; Kretzschmar, H.-J.; Lovell-Smith, J. W.; McDougall, T. J.; Pawlowicz, R.; Ridout, P.; Seitz, S.; Spitzer, P.; Stoica, D.; Wolf, H.:
  Metrological challenges for measurements of key climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview.
  Metrologia 53 (2016), pp. R1-R11, doi: 10.1088/0026-1394/53/1/R1.
- Pawlowicz, R.; Feistel, R.; McDougall, T. J.; Ridout, P.; Seitz, S.; Wolf, H.:
  Metrological challenges for measurements of key climatological observables Part 2: Oceanic salinity.
  Metrologia 53 (2016), pp. R12-R25, doi: 10.1088/0026-1394/53/1/R12.

- Dickson, A. G.; Camões, M. F.; Spitzer, P.; Fisicaro, P.; Stoica, D.; Pawlowicz, R.; Feistel, R.: Metrological challenges for measurements of key climatological observables. Part 3: Seawater pH. Metrologia 53 (2016), pp. R26-R39, doi: 10.1088/0026-1394/53/1/R26.
- Lovell-Smith, J. W.; Feistel, R.; Harvey, A. H.; Hellmuth, O.; Bell, S. A.; Heinonen, M.; Cooper, J. R.:
  Metrological challenges for measurements of key climatological observables. Part 4: Atmospheric relative humidity.
  Metrologia 53 (2016), pp. R40-R59, doi: 10.1088/0026-1394/53/1/R40.
- Feistel, R.; Lovell-Smith, J. W.; Hellmuth, O. (Proposers):
  Guideline on a Virial Equation for the Fugacity of H2O in Humid Air.
  The International Association for the Properties of Water and Steam.
  Stockholm, Sweden, July 2015. Available at www.iapws.org.
- Feistel, R.:
  Salinity and relative humidity: climatological relevance and metrological needs.
  Acta Imeko 4, No. 4 (2015), 57-61.
- Feistel, R.; Lovell-Smith, J. W.; Hellmuth, O.:
  Virial Equation for the Fugacity of Water in Humid Air.
  Int. J. Thermophys. 36 (2015), pp. 44-68.
- Feistel, R.; Lovell-Smith, J. W.; Hellmuth, O.:
  Erratum to: Virial Approximation of the TEOS-10 Equation for the Fugacity of Water in Humid Air.
  Int. J. Thermophys. 36 (2015), p. 204.
- Kretzschmar, H.-J.; Herrmann, S.; Feistel, R.; Wagner, W.:
  The International IAPWS Formulation for the Thermodynamic Properties of Seawater for Desalination Processes.
  The International Desalination Association World Congress on Desalination and Water Reuse, San Diego, CA, USA (2015), doi: 10.13140/RG.2.1.4734.7444.
- Kretzschmar, H.-J.; Feistel, R.; Wagner, W.; Miyagawa, K.; Harvey, A. H.; Cooper, J. R.; Hiegemann, M.; Blangetti, F. L.; Orlov, K. A.; Weber, I.; Singh, A.; Herrmann, S.:
  The IAPWS Industrial Formulation for the Thermodynamic Properties of Seawater.
  Desalination and Water Treatment 55 (2015), pp. 1177-1199,
  doi: 10.1080/19443994.2014.925838.

German Aerospace Center (DLR), Cologne
Institute of Propulsion Technology
Prof. Dr. Francesca di Mare

Project

1. Implementation of the Fast Steam Property Algorithms Based on Spline Interpolation into the CFD Code TRACE
   - The draft “IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)” has been implemented into the CFD code TRACE.
   - On this basis the implementation has been further improved, especially regarding the software architecture, solution algorithm and boundary treatment.

- The capability of the SBTL-method has been tested on Laval-nozzle and Cascade test cases. The calculation of a real steam engine configuration is targeted next.

Recent Publications

- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Friend, D. G.; Harvey, A.H.: Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL),
  J. Eng. Gas Turbines Power (2016), in preparation.

Leibniz Institute for Tropospheric Research, Leipzig
Dr. Olaf Hellmuth

Projects

1. Investigation on Virial Approximation for Humid Air
2. Preparation of a paper about Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air

Recent Publications

- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.: Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air.
  Int. J. Thermophys. (2016), in preparation.
- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.: Digital Supplement to "Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air".
  Int. J. Thermophys. (2016), in preparation.
- Feistel, R.; Wielgosz, R.; Bell, S. A.; Camões, M. F.; Cooper, J. R.; Dexter, P.; Dickson, A. G.; Fisicaro, P.; Harvey, A. H.; Heinonen, M.; Hellmuth, O.; Kretzschmar, H.-J.; Lovell-Smith, J. W.; McDougall, T. J.; Pawlowicz, R.; Ridout, P.; Seitz, S.; Spitzer, P.; Stoica, D.; Wolf, H.: Metrological challenges for measurements of key climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview.
  Metrologia 53 (2016), pp. R1-R11, doi: 10.1088/0026-1394/53/1/R1.
- Pawlowicz, R.; Feistel, R.; McDougall, T. J.; Ridout, P.; Seitz, S.; Wolf, H.:
  Metrological challenges for measurements of key climatological observables Part 2: Oceanic salinity.
  Metrologia 53 (2016), pp. R12-R25, doi: 10.1088/0026-1394/53/1/R12.
- Lovell-Smith, J. W.; Feistel, R.; Harvey, A. H.; Hellmuth, O.; Bell, S. A.; Heinonen, M.; Cooper, J. R.:
  Metrological challenges for measurements of key climatological observables. Part 4: Atmospheric relative humidity.
  Metrologia 53 (2016), pp. R40-R59, doi: 10.1088/0026-1394/53/1/R40.
- Hellmuth, O.:
  Selected Aspects of New Particle Formation in the Earth Atmosphere: Phenomenology and Mechanistic Description.
  In: Schmelzer, J. W. P.; Hellmuth, O. (eds.): Nucleation Theory and Applications. Special Issues. Review Series on Selected Topics of Atmospheric Sol Formation: Volume 2. Joint Institute for Nuclear Research, Dubna, Russia (2016), in technical revision.

- Hellmuth, O.:
  Selected Aspects of New Particle Formation in the Earth Atmosphere: Organic Aerosol Formation and Pre-Nucleation Molecular Clustering.
  In: Schmelzer, J. W. P.; Hellmuth, O. (eds.): Nucleation Theory and Applications. Special Issues. Review Series on Selected Topics of Atmospheric Sol Formation: Volume 3. Joint Institute for Nuclear Research, Dubna, Russia (2016), in technical revision.
- Hellmuth, O.:
  Selected Aspects of New Particle Formation in the Earth Atmosphere: Ion-Mediated Aerosol Formation.
  In: Schmelzer, J. W. P.; Hellmuth, O. (eds.): Nucleation Theory and Applications. Special Issues. Review Series on Selected Topics of Atmospheric Sol Formation: Volume 4. Joint Institute for Nuclear Research, Dubna, Russia (2016), in technical revision.
- Lovell-Smith, J. W.; Feistel, R.; Hellmuth, O.:
  Toward a fundamental definition of relative humidity.
  TEMPMEKO 2016, XIII International Symposium on Temperature and Thermal Measurements in Industry and Science, June 26-July 1, 2016.
- Feistel, R.; Lovell-Smith, J. W.; Hellmuth, O.:
  Virial Approximation of the TEOS-10 Equation for the Fugacity of Water in Humid Air.
  Int. J. Thermophys. 36 (2015), pp. 44-68.
- Feistel, R.; Lovell-Smith, J. W.; Hellmuth, O.:
  Erratum to: Virial Approximation of the TEOS-10 Equation for the Fugacity of Water in Humid Air.
  Int. J. Thermophys. 36 (2015), p. 204.
- Hellmuth, O.; Shchekin, A. K.:
  Determination of interfacial parameters of a soluble particle in a nonideal solution from measured deliquescence and efflorescence humidities.
  Atmos. Chem. Phys. 15 (2015), pp. 3851-3871.
- Hellmuth, O.; Shchekin, A. K.:
  Supplement of "Determination of interfacial parameters of a soluble particle in a nonideal solution from measured deliquescence and efflorescence humidities".
  Supplement of Atmos. Chem. Phys. 15 (2015), pp. 3851-3871.
- Feistel, R.; Lovell-Smith, J. W.; Hellmuth, O. (Proposers):
  Guideline on a Virial Equation for the Fugacity of H2O in Humid Air.
  The International Association for the Properties of Water and Steam.
  Stockholm, Sweden, July 2015. Available at www.iapws.org.

Physikalisch-Technische Bundesanstalt Braunschweig und Berlin, Braunschweig
Dr. Henning Wolf

Recent Publications

- Schmidt, H.; Wolf, H.; Hassel, E.:
  A method to measure the density of seawater accurately to the level of 10^{-6}.
  Metrologia 53 (2016), pp. 770–786, doi: 10.1088/0026-1394/53/2/770.

- Feistel, R.; Wielgosz, R.; Bell, S. A.; Camões, M. F.; Cooper, J. R.; Dexter, P.; Dickson, A. G.; Fisicaro, P.; Harvey, A. H.; Heinonen, M.; Hellmuth, O.; Kretzschmar, H.-J.; Lovell-Smith, J. W.; McDougall, T. J.; Pawlowicz, R.; Ridout, P.; Seitz, S.; Spitzer, P.; Stoica, D.; Wolf, H.:
  Metrological challenges for measurements of key climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview.
  Metrologia 53 (2016), pp. R1–R11.
- Pawlowicz, R.; Feistel, R.; McDougall, T. J.; Ridout, P.; Seitz, S.; Wolf, H.:
  Metrological challenges for measurements of key climatological observables Part 2: Oceanic salinity.
  Metrologia 53 (2016), pp. R12-R25, doi: 10.1088/0026-1394/53/1/R12.

Ruhr University Bochum
Faculty of Mechanical Engineering, Department of Thermodynamics
Prof. Dr. Roland Span

Projects:

1. The first version of a new standard property model for CCS relevant mixtures was published by Gernert and Span (2016). This work is especially focused on humid mixtures, since existing models from the GERG-2008 package for natural gases are not designed for higher concentrations of water. The published version of the CCS mixture model will continuously be extended to further components. The current (still unpublished) status of the model enables a description of mixtures containing carbon dioxide, water, carbon monoxide, nitrogen, argon, oxygen, methane, hydrogen, hydrogen sulfide, sulfur dioxide, hydrogen chloride, chlorine, mono-, and diethanolamine. The proceeding development of this mixture model includes the generalized description of binary systems with a very limited data base as well as fitting binary-specific functions for well investigated systems (e.g. water + methane). All models are implemented in the software package TREND by Span et al. (2015), which is already used by more than 50 groups in academia and industry.
2. The work on models describing hydrate formation has been continued in cooperation with Dr. V. Vinš, Dr. J. Hrubý and Dr. A. Jäger. Dr. Jäger has changed to TU Dresden after completing his Ph.D. and is involving the thermodynamics group led by Prof. Dr. C. Breitkopf into the work on hydrates now as well. Three journal articles describing the status of the hydrate model in detail have been submitted. Two are available in print by now, one is still under revision (see literature). S. Hielscher will continue this work at RUB. The current (still unpublished) status of the hydrate model allows for a description of first mixed hydrates as well; to extend this status to further hydrate forming components is ongoing work. Funding for this important project has been granted by the German Science Foundation (DFG). A follow up proposal is currently under preparation.
3. The development of a new reference equation of state for heavy water is ongoing. This work is linked to an IAPWS grant awarded in 2012 and to a close cooperation with Dr. A. H. Harvey and Dr. E. W. Lemmon at NIST in Boulder. Current work is focused on improving the description of 2nd virial coefficient data that became available in 2015. For the final equation of state a careful evaluation of the experimental uncertainties of all published data sets is carried out to ensure the most consistent description of the whole fluid region. New data for the 3rd virial coefficient and the heat capacity of the ideal gas will be provided by other IAPWS groups to enhance the fitting process.

Recent Publications

- Gernert, J.; Span, R.:
  EOS-CG: A Helmholtz energy mixture model for humid gases and CCS mixtures.
  J. Chem. Thermodyn. 93 (2016), pp. 274-293.

- Vinš, V.; Jäger, A.; Span, R.; Hrubý, J.:
  Model for gas hydrates applied to CCS systems part I. Parameter study of the van der Waals and Platteeuw model.
  Fluid Phase Equilib. 427 (2016), pp. 268-281.
- Jäger, A.; Vinš, V.; Span, R.; Hrubý; J.:
  Model for gas hydrates applied to CCS systems part III. Results and implementation in TREND.
  Fluid Phase Equilib. 429 (2016), pp. 55-66.
- Vinš, V.; Jäger, A.; Span, R.; Hrubý, J.:
  Model for gas hydrates applied to CCS systems part II. Fitting of the model parameters.
  Fluid Phase Equilib. (2016), submitted.
- Span, R.; Eckermann, T.; Herrig, S.; Hielscher, S.; Jäger, A.; Thol, M.:
  TREND. Thermodynamic Reference and Engineering Data 2.0.1.
  Lehrstuhl für Thermodynamik, Ruhr-Universität Bochum, Bochum, Germany (2015).

Ruhr University Bochum
Faculty of Mechanical Engineering, Chair of Thermodynamics
Prof. em. Dr. Dr. e. h. Wolfgang Wagner

Projects

1. Investigation on a possible improvement of the uncertainty of IAPWS-95 in isobaric heat capacity in the liquid region near the melting line at high pressures. The results will be presented at the 2016 IAPWS Meeting in Dresden.
2. Working on a proposed improvement of the IAPWS-95 Release concerning the uncertainty of IAPWS-95 in isobaric heat capacity and a more accurate statement on the extrapolation into the metastable region “subcooled liquid”.

Recent Publications

- Wagner, W., Thol, M.:
  The Behavior of IAPWS-95 from 250 to 300 K and Pressures up to 400 MPa: Evaluation Based on Recently Derived Property Data.
  J. Phys. Chem. Ref. Data 44 (2015), pp. 043102.
- Kretzschmar, H.-J.; Feistel, R.; Wagner, W.; Miyagawa, K.; Harvey, A. H.; Cooper, J. R.; Hiegemann, M.; Blangetti, F. L.; Orlov, K. A.; Weber, I.; Singh, A.; Herrmann, S.:
  The IAPWS Industrial Formulation for the Thermodynamic Properties of Seawater.
  Desalination and Water Treatment 55 (2015), pp. 1177-1199,
  doi: 10.1080/19443994.2014.925838.
- Kretzschmar, H.-J.; Herrmann, S.; Feistel, R.; Wagner, W.:
  The International IAPWS Formulation for the Thermodynamic Properties of Seawater for Desalination Processes.
  The International Desalination Association World Congress on Desalination and Water Reuse, San Diego, CA, USA (2015), doi: 10.13140/RG.2.1.4734.7444.

Siemens Energy Solutions, Erlangen
Michael Rziha

Projects

1. Development of new Technical Guidance Documents:
   - Application of Film Forming Amines in Fossil, Combined Cycle, and Biomass Power Plants

- HRSG High Pressure Evaporator Sampling for Internal Deposit Identification and Determining the Need to Chemical Clean
- Both documents are ready to be adopted by the EC in Stockholm.

2. Developing of drafts for a new technical guidance documents
   - "Ensuring the Integrity and Reliability of Demineralised Make-up Water Supply to the Unit Cycle", to be discussed within PCC Working Group during the Dresden meeting.
   - "Corrosion Product Sampling for Cycling Plants", to be discussed within PCC Working Group during the Dresden meeting.

Siemens Energy Solutions, Erlangen
Ingo Weber, Stefan Bennoit, Julien Bonifay

Projects

1. Implementation of the fast steam property spline-interpolation algorithms into the heat cycle simulation code KRAWAL
   - The draft "IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)" has been implemented into the heat cycle code KRAWAL which is used worldwide by Siemens.
   - The computing time consumption of KRAWAL has been significantly reduced.
2. Implementation of the fast steam property spline-interpolation algorithms into the non-stationary power-plant simulation code DYNAPLANT
   - The draft "IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)" has been implemented into the non-stationary power-plant simulation code DYNAPLANT.
   - The computing time consumption of DYNAPLANT has been significantly reduced.

Recent Publications

- Kretzschmar, H.-J.; Feistel, R.; Wagner, W.; Miyagawa, K.; Harvey, A. H.; Cooper, J. R.; Hiegemann, M.; Blangetti, F. L.; Orlov, K. A.; Weber, I.; Singh, A.; Herrmann, S.: The IAPWS Industrial Formulation for the Thermodynamic Properties of Seawater. Desalination and Water Treatment 55 (2015), pp. 1177-1199.
- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Friend, D. G.; Harvey, A.H.: Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL), J. Eng. Gas Turbines Power (2016), in preparation.

STEAG Energy Services, Zwingenberg
Dr. Reiner Pawellek, Dr. Tobias Löw

Project

1. Implementation of the fast steam property spline-interpolation algorithms into the heat cycle simulation code EBSILON
   - The draft "IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)" has been implemented into the heat cycle code EBSILON which is used worldwide by the power industry.
   - The computing time consumption of EBSILON has been significantly reduced.

Recent Publications

- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Friend, D. G.; Harvey, A.H.: Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL),
  J. Eng. Gas Turbines Power (2016), in preparation.

Zittau/Goerlitz University of Applied Sciences
Department of Technical Thermodynamics
Prof. Dr. Hans-Joachim Kretzschmar

Projects

1. Development of fast property algorithms based on spline interpolation
   - The draft "IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (SBTL)" has been completed and adopted by IAPWS
   - Spline property algorithms were developed for functions of the variables specific volume and specific internal energy (v,u) and related inverse functions for water and steam based on the scientific formulation IAPWS-IF95.
   - The range of validity of the spline-property functions based on IAPWS-IF97 has been expanded to metastable subcooled steam and metastable superheated liquid water.
   - Spline property algorithms have been developed for functions of the variables specific volume an specific enthalpy (v,h) as well as for the related inverse functions for water and steam based on the industrial formulation IAPWS-IF97.
2. Application of the developed spline algorithms for calculating thermodynamic properties

   The developed spline property algorithms have been implemented into the following process simulation codes:
   - Non-stationary thermo-hydraulic cycle program RELAP-7 of the Idaho National Institute INL
   - Heat cycle simulation program EBSILON of STEAG Energy Services
   - Heat cycle simulation program KRAWAL of Siemens Energy Solutions
   - Non-stationary heat cycle program DYNAPLANT of Siemens Energy Solutions.
3. Updating the algorithms for calculating transport properties of moist air and working on the ASHRAE Research Project 1767

Recent Publications

- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.: Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air.
  Int. J. Thermophys. (2016), in preparation.
- Hellmuth, O.; Feistel, R.; Lovell-Smith, J. W.; Kalová, J.; Kretzschmar, H.-J.; Herrmann, S.: Digital Supplement to "Virial Approximation of the TEOS-10 Equation for the Enhancement Factor of Water in Humid Air".
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- Kunick, M.; Kretzschmar, H.-J.; Gampe, U.; di Mare, F.; Hrubý, J.; Duška, M.; Vinš, V.; Singh, A.; Miyagawa, K.; Weber, I.; Pawellek, R.; Novi, A.; Blangetti, F.; Friend, D. G.; Harvey, A.H.: Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL),
  J. Eng. Gas Turbines Power (2016), in preparation.
- Feistel, R.; Wielgosz, R.; Bell, S. A.; Camões, M. F.; Cooper, J. R.; Dexter, P.; Dickson, A. G.; Fisicaro, P.; Harvey, A. H.; Heinonen, M.; Hellmuth, O.; Kretzschmar, H.-J.; Lovell-Smith, J. W.; McDougall, T. J.; Pawlowicz, R.; Ridout, P.; Seitz, S.; Spitzer, P.; Stoica, D.; Wolf, H.: Metrological challenges for measurements of key climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview.
  Metrologia 53 (2016), pp. R1–R11.
- Vogel, E., Span, R., Herrmann, S.:
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  J. Phys. Chem. Ref. Data 44 (2015), 0431011.
- Herrmann, S.; Vogel, E.:
  Viscosity and Density of Normal Butane Simultaneously Measured at Temperatures from (298 to 448) K and at Pressures up to 30 MPa Incorporating the Near-Critical Region.
  J. Chem. Eng. Data 60 (2015), 3703–3720.
- Herrmann, S.; Hassel, E.; Vogel, E.:
  Viscosity and Density of Isobutane Measured in Wide Ranges of Temperature and Pressure Including the Near-Critical Region.
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- Kunick, M.; Kretzschmar, H.-J.; di Mare, F.; Gampe, U.:
  CFD Analysis of Steam Turbines with the IAPWS Standard on the Spline-Based Table Look-Up Method (SBTL) for the Fast Calculation of Real Fluid Properties.
  In: Proceedings of ASME Turbo Expo 2015: Turbine Technical Conference and Exposition. GT2015, Montreal, Canada (2015). ISBN: 978-0-7918-5679-6
- Herrmann, S.; Hassel, E.; Vogel, E.:
  Simultaneous Viscosity-Density Measurements of Gases over a Wide Range of Temperature and Pressure Using a Vibrating-Wire Viscometer and a Single-Sinker Densimeter.
  In: Young Scientist 2015 9th International Conference of Young Scientists of the Academic Coordination Centre in the Euroregion Neisse, Adamczuk, F.; Adamczuk, J. (Hrsg.), Publishing House Wydawnictwo 'AD REM': Jelenia Gora (2015), 31-40, ISBN: 978-83-65295-16-3.
- Kretzschmar, H.-J.; Feistel, R.; Wagner, W.; Miyagawa, K.; Harvey, A. H.; Cooper, J. R.; Hiegemann, M.; Blangetti, F. L.; Orlov, K. A.; Weber, I.; Singh, A.; Herrmann, S.:
  The IAPWS Industrial Formulation for the Thermodynamic Properties of Seawater.
  Desalination and Water Treatment 55 (2015), pp. 1177-1199,
  doi: 10.1080/19443994.2014.925838.
- Kretzschmar, H.-J.; Herrmann, S.; Feistel, R.; Wagner, W.:
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Current Status of Research Activities in Japan
Submitted to the Executive Committee Meeting, IAPWS, Dresden, Germany, September 2016

Japanese National Committee, Chaired by Professor Masaru Nakahara
International Association for the Properties of Water and Steam
c/o The 139th Committee on Steam Properties
Japan Society for the Promotion of Science (JSPS)
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I. Overview:

Recently we focus on the contribution to the activities of IAPWS for the development of such documents as the TGD guidance, guidelines, releases etc. Also our efforts are directed to the effective distribution and bilingual availability of the internationally standardized references among our colleagues. Some fundamental research activities on water and aqueous systems, relevant closely or in future to IAPWS, are actively carried out all over our country as can be seen in the publication list below. They can be characterized by key words, such as water, hydrothermal, solvothermal, solvation, interfacial, organic, ionic, and reactions. Some of them are presented by our colleagues in the IAPWS annual meeting in Dresden, Germany. We often hold the national meeting to exchange a wide range of information on the science and technology related to power generation. Industrial and academic people are collaborating in a stimulating manner to seek the present or future problems. Our members cover a variety of IAPWS-related areas and make efforts to seriously consider the improvement of our power cycle systems and operation and safety engineering including the outlet gas treatment to avoid the public nuisance such as air/water/soil pollution. One of the J-Power members, JPE, has been developing “Regenerative Activated Coke Technology” as one of the eminent front runners. Now we are preparing the coming meeting of IAPWS 2017 in Kyoto.

II. Recent Publications:

Nakahara, Masaru
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[2] Yoshida, K.; Matubayasi, N.; Nakahara, M.; Uosaki, Y.; “Effect of Rotation on Vibrational Spectrum of Supercritical Water: Analysis of Dependencies on Density and Hydrogen Isotopes”, *The Review of High Pressure Science and Technology*, **26**, in press (2016).

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[1] Nakahara, M.; Yoshida K.; "Chronological Scientific Tables 2016", pp.502-509, 514-517, Maruzen Publishing Co., Ltd., Tokyo, ISBN 978-4621089651 (2015).

[2] Yoshida, K.; Matubayasi, N.; Nakahara, M.; Uosaki, Y.; "Effect of Rotation on Vibrational Spectrum of Supercritical Water: Analysis of Dependencies on Density and Hydrogen Isotopes", *The Review of High Pressure Science and Technology*, **26**, in press (2016).

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International Association for the Properties of Water and Steam
Russian National Committee (RNC)
Report Second Half-Year of 2015- First Half-Year of 2016

- RNC active participation in organization of next seminars for engineers and technology specialist from Russian power engineering companies:
    1. Cycle chemistry at power plants;
    2. Today technologies for cycle chemistry monitoring systems;
    3. Today experience of water treatment systems operation;
    4. Water treatment and cycle chemistry for combine cycle power plants.
- Three meetings of RNC have been held. Current problems are investigated.

Publications list

1. Akinfiev, N.N., Plyasunov, A.V., Pokrovski, G.S. An equation of state for predicting the thermodynamic properties and vapour-liquid partitioning of aqueous Ge(OH)4 in a wide range of water densities. Fluid Phase Equilibria. Volume 392, 25 April 2015, Pages 74–83
2. Akinfiev, N.N., Zotov, A.V. Solubility of chlorargyrite (AgCl(cr./l.)) in water: New experimental data and a predictive model valid for a wide range of temperatures (273-873 K) and water densities (0.01-g·cm^{-3}) Geochimica et Cosmochimica Acta. Geochimica et Cosmochimica Acta 178 · February 2016
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5. Petrova, T.I., Dyachenko, F.V., Bogatyreva, Y.V., Borodastov, A.K., Ershova, I.S. Effect of polyamine reagents on exchange capacity in ion exchangers. Thermal Engineering. 2016, Vol. 63, No. 5, pp. 379–383.
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18. Egoshina O.V., Latt A.M., Nazarenko M.P., Tabakov I.A., Shumilov Yu.L. Experience in application of automated sample preparation system in chemistry control system. Power Engineer. 2015 (7) 48-52 (*Russian*)
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23. Ustyuzhanin E.E., Ochkov V.F., Shishakov V.V., Rykov A.V. Extrapolation of IAPWS-IF97 data: The saturation pressure of H2O in the critical region // XXX International Conference on Interaction of Intense Energy Fluxes with Matter. March 1-6, 2015, Elbrus, Kabardino-Balkaria, Russia
24. Ochkov V. New generation of computer-aided tools for thermal calculation // Proceedings of the conference “Power System Engineering, Thermodynamics and Fluid Flow“. 9-10 June 2016. Pilsen. Czech Repumlic

25. G.U. Badranova, I.A. Staroselsky, N.A. Pronina, P.M. Gotovtsev. Synthesis and investigation of polymer hydrogels with integrated TiO_2 nanoparticles. Synchrotron and neutron researches – SynNANO 2015. P. 17-18 (*Russian*)
26. Borgolov A.V., Gotovtsev P.M., Vasilov R.G. Development of biodiesel production technology in flow bioreactor with immobilization of yeast cells on polyakrilamide. V International conference "Marine and food biotechnology" Kaliningrad 2016 p. 16-18. (*Russian*)

The Swiss National Committee

International Association for the Properties of Water and Steam

Report on IAPWS related activities – June 2015 / September 2016

Submitted to the EC Meeting of IAPWS, Dresden, Germany - September 2016.

National Committee Contacts:
SCPWS Swiss Committee for the Properties of Water and Steam; www.scpws.ch
President: Marco Lendi, E-mail: marco.lendi@swan.ch
Secretary: Tapio Werder, E-mail: tapio.werder@waesseri.com

Following Institutions participated in the research into the thermophysical properties and chemical processes:

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Dr. Michael Hiegemann, General Electric (Switzerland) GmbH, Baden, Switzerland, E-Mail: michael.hiegemann@ge.com
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Marco Lendi, Swan Analytical Instruments, Hinwil, E-Mail: marco.lendi@swan.ch
Tapio Werder, PowerPlant Chemistry Journal, Hinwil, E-Mail: tapio.werder@waesseri.com

Research activities in the reporting period:
No new projects were reported

Contributions to current IAPWS activities:
Vice-chairman of Subcommittee on Sea-Water: M. Hiegemann
Vice-chairman of PCC Sub-Task Group on Film Forming Amines (FFA): Marco Lendi

Status of Associate Membership to IAPWS:
Up to now, no team of sponsors to commit on mid- or long-term to a regular Swiss membership fee has yet been assembled. Activities were therefore limited to few individuals. In August 2016 the new webpage has been released. SCPWS is going to host the International Conference on Film Forming Amines and Products in April 2017 in Lucerne, Switzerland. The organization of this conference has been the main activity of the board of SCWPS in the past weeks. This conference in Lucerne will also serve to promote SCPWS within Switzerland and to find new participating institutions.
- It is requested to extend the Associate Membership for another term.

M. Lendi, September 2016

U.S. National Committee to IAPWS

2016 Report on Activities of Potential Interest to IAPWS

Communicated from the Applied Chemicals and Materials Division, National Institute of Standards and Technology, Boulder, CO:

- In a collaboration with the Ruhr University of Bochum (Germany), we continue to work on an IAPWS project for an equation of state for the thermodynamic properties of heavy water. A preliminary equation has been developed, and will be refined and augmented soon by some new data for the ideal-gas heat capacity and for the second and third virial coefficients.
- Work is beginning on a related IAPWS project to develop new transport property correlations for heavy water.
- In collaboration with researchers at Fondazione Bruno Kessler (Italy), Nicolaus Copernicus University (Poland), and the University of Delaware (USA), two state-of-the-art flexible model for the water pair potential have been used to calculate second virial coefficients $B(T)$ for both H_2O and D_2O. Calculations for the third virial coefficient $C(T)$, which also utilize state-of-the-art 3-body potentials, are in progress. The calculations use the path-integral Monte Carlo method, which fully accounts for both intermolecular and intramolecular quantum effects. The results so far agree with experimental data, but cover a wider range of temperatures. The effect of molecular flexibility is found to be significant in comparison to the uncertainty of the calculations and of the experimental data, implying that the rigid models often used for water are insufficient if the best quantitative accuracy for virial coefficients is desired.

Communicated from the University of Maryland, College Park

- Research is predicting a new type of fluctuation-induced pressure in confined liquid layers subjected to a temperature gradient. Estimates of the magnitude of these non-equilibrium pressures in a layer of liquid water have been presented.

T.R. Kirkpatrick, J.M. Ortiz de Zarate, and J.V. Sengers, Phys. Rev. E 93, 012148 (2016); ibid. 93, 032117 (2016).

- Additional publications of potential interest

Water: A Tale of Two Liquids, Gallo, P; Arnann-Winkel, K; Angell, CA; Anisimov, MA; Caupin, F; Chakravarty, C; Lascaris, E; Loerting, T; Panagiotopoulos, AZ; Russo, J; Sellberg, JA; Stanley, HE; Tanaka, H; Vega, C; Xu, LM; Pettersson, LGM. CHEMICAL REVIEWS 116 (13) 7463-7500 DOI: 10.1021/acs.chemrev.5b00750 pub. JUL 13 2016

Hydrophobicity and thermodynamic response for aqueous solutions of amphiphiles, Zemankova, K; Troncoso, J; Cerdeirina, CA; Romani, L; Anisimov, MA. CHEMICAL PHYSICS 472, 36-43 DOI: 10.1016/j.chemphys.2016.02.020 pub. JUN 15 2016

Two-state thermodynamics and the possibility of a liquid-liquid phase transition in supercooled TIP4P/2005 water, Singh, RS, Biddle, JW; Debenedetti, PG; Anisimov, MA. JOURNAL OF CHEMICAL PHYSICS 144 (14) Article Number: 144504, DOI: 10.1063/1.4944986 pub. APR 14 2016

Mesoscale solubilization and critical phenomena in binary and quasi-binary solutions of hydrotropes, Robertson, AE; Phan, DH; Macaluso, JE; Kuryakov, VN; Jouravleva, EV ; Bertrand, CE; Yudin, IK; Anisimov, MA FLUID PHASE EQUILIBRIA 407, 243-254 SI DOI: 10.1016/j.fluid.2015.06.030 pub. JAN 15 2016

Communicated from the ASME Research & Technology Committee on Water and Steam in Thermal Systems

- The *Consensus on Pre-Commissioning Stages for Cogeneration and Combined Cycle Power Plants* document, which serves to inform, educate and assist the reader in adequately considering and planning for the many major activities involved in the design, construction and start-up of cogeneration and combined cycle power plants, is nearly ready for release and publication by ASME.

The Water Technology Subcommittee is working on an update to the ASME "brown book," *Consensus on Operating Practices for the Control of Feedwater and Boiler Water Chemistry in Modern Industrial Boilers*; this ASME publication provides a consensus of proper current operating practices for the control of feedwater and boiler water chemistry in the operation of industrial and institutional, high duty, primary fuel fired boilers. These practices are aimed at minimizing corrosion, deposition, cleaning requirements, and unscheduled outages in the steam generators and associated condensate, feedwater, and steam systems. The publication will be an expansion as well as a revision of the operating practice consensus documents previously issued by the Committee in 1994 to include advances in boiler design and water treatment technology.

Communicated from Scripps Institution of Oceanography

- Scripps continues involvement in SCOR Working Group (WG-145) that will — in part — address the need for a suitable activity coefficient model for seawater that can be used to further the goal of establishing a suitable seawater pH definition that is metrologically traceable. This group met in February 2016 in New Orleans, and Scripps and University of East Anglia, UK have put in a joint proposal to the UK-NERC (and US-NSF) to work on developing the proposed Pitzer-type model, combining both an evaluation of pre-existing data, as well as the measurement of additional new data that is needed to meet the goal.

Communicated from OLI Systems

- **Aqueous solution chemistry of rare-earth elements**

OLI Systems continued its research on the properties of aqueous solutions of rare-earth elements within the framework of the Department of Energy's Critical Materials Institute. OLI Systems provides simulation tools for other members of the institute. In a recently completed project, a thermodynamic model of rare earth elements in the presence of complexing agents (i.e., citrates, gluconates, and acetates) has been established. This model has been utilized to rationalize the stripping of rare-earth cations adsorbed on bacterial cells using lanthanide binding tags. This work has been published in:

Park, D., Reed, D., Yung, M., Eslamimanesh, A., Lencka, M., Anderko, A., Fujita, Y., Riman, R.E., Navrotsky, A., Jiao, Y., "Bioadsorption of Rare Earth Elements through Cell Surface Display of Lanthanide Binding Tags," *Environmental Science & Technology*, 50 (2016) 2735-2742.

A comprehensive analysis of the thermodynamic behavior of rare earth chlorides is nearing completion.

- **Amines**

A major effort has been devoted to developing a comprehensive model for the phase behavior of amines and corresponding amine hydrochlorides in aqueous systems. The amines considered in this work are used as neutralizers in the power generation and refining industries. The model has been described for selected amines in the following paper:

M.M. Lencka, J.J. Kosinski, P. Wang, and A. Anderko, "Thermodynamic modeling of aqueous systems containing amines and amine hydrochlorides: Application to methylamine, morpholine, and morpholine derivatives," *Fluid Phase Equilibria*, 418 (2016) 160-174

- **Other topics**

A model has been developed for various sodium phosphates in aqueous environments. The model is valid for temperatures up to 350 C and includes speciation, solid-liquid equilibria, vapor-liquid equilibria and liquid-liquid equilibria at high temperatures. The liquid-liquid equilibrium shows a lower critical end point and is strongly dependent on the Na/P ratio.

Work has been completed on modeling the behavior of actinides (U, Np, Pu, Am, Cm) at the most important oxidation states in the presence of acids, bases, carbon dioxide, carbonates, chlorides, nitrates and other salts. The model predicts the solubility and speciation of actinides in wide ranges of concentrations, ranging from dilute solutions that are relevant to the environmental fate of radionuclides to very concentrated solutions in nitric acid, which are used in nuclear fuel processing. Also, a model has been developed for predicting the behavior of lead species, including various lead silicates, molybdate, tungstate and acetate, formate and nitrate.

Work is in progress on simulating the behavior of calcium, magnesium, and zinc silicates in aqueous systems. This project is motivated primarily by the need to predict phenomena associated with SAGD (steam-assisted gravity drainage) processes.

In a separate project, work is ongoing on modeling the solubility of scale-forming minerals in oil and gas production. These minerals include $BaSO_4$, $CaCO_3$, $CaSO_4$, ZnS, and PbS.

Participants

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Williams	Richard	Dr.	United Kingdom					
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Sengers	Jan	Prof.	United States		1			
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Friend	Daniel		United States		1	1		
Carvalho	Luis		United States					