MINUTES

IAPWS THERMOPHYSICAL PROPERTIES OF WATER AND STEAM WG
WITNEY, UNITED KINGDOM SEPTEMBER 4-7, 2006

NOTE: Items are listed according to their order on the agenda, which is attached as Attachment A. **Bold print** denotes significant actions. These minutes include some items (5-11, 13-16, 19.6) that were done jointly with the WG IRS and some (18) with PCAS, and also record (item 17) the workshop on seawater held by all 4 Working Groups.

1-3. The meeting was opened at 8:40 AM on Monday, September 4 by the Chair, Hans-Joachim Kretzschmar, who began by informing the WG about two of its members (Prof. Skripov and Dr. Watson) who had died in the previous year. R. Feistel gave a brief appreciation of Prof. Skripov, and J. Sengers gave a brief appreciation of Dr. Watson, followed by a moment of silence. It was announced that WG member J.M.H. Levelt Sengers had won the ASME Touloukian award for outstanding contributions to knowledge in the area of thermophysical properties. The agenda (Attachment A) was adopted after a few revisions. Allan Harvey was appointed Clerk of Minutes. The minutes of the 2005 TPWS WG meeting in Santorini were approved.

4. No new collaborative projects were proposed by the WGs TPWS or IRS for this year.

5. J. Hruby presented the report of the Evaluation Committee on the proposed release for the thermodynamic properties of ice, which was favorable. **The WGs TPWS and IRS voted unanimously to approve the proposed release and recommend its adoption by the EC.**

6. R. Feistel presented a new calculation of the sublimation curve of ice based on the new ice thermodynamic formulation and IAPWS-95, along with some consideration of low-temperature heat capacities. A new melting curve for ice-I can be computed in a similar way, but does not quite meet the (L-I-III) triple point used in the current IAPWS formulation. Issues were discussed such as whether temperature or pressure should be the independent variable in such formulations, and whether correlations for properties (enthalpy, etc.) at saturation, or their differences, would be useful. **A Task Group was appointed to consider these issues and work toward a Supplementary Release, with members Feistel (Chair), Wagner, Harvey, and Hruby. The Chair of TPWS was authorized to appoint an Evaluation Task Group during the year if progress of the work was fast enough for this to be appropriate.**

7. R. Feistel and A. Harvey presented some material on the prospects for achieving an improved description of the ideal-gas heat capacity of water. Better data are available for this computation at high temperature (especially above about 2000 K), and the new formulation might go to lower temperatures than the one currently used (which extends down to 130 K). It was decided that this effort would probably not be an official IAPWS document, but the presenters were encouraged to pursue it and to consult R. Span in the effort. The question was raised of how high in temperature to go with this calculation, and the consensus answer was as high as is feasible. The work mentioned above on a new formulation of the sublimation curve may wait until this new ideal-gas result is available.

8. [This item is reported in the IRS minutes.]

9.1 J. Sengers reported on the development of the new viscosity correlation. It was recognized by all that the Evaluation Task Group had contributed greatly to the improvement of this effort. Prof. Watanabe wished to state for the record the exemplary contributions of the Evaluation Task Group and also his feeling that the earlier effort presented in Santorini had been too rushed. Some discussion ensued about the proposed document, and suggestions for improvement were made. The need was expressed to pay attention to the part of the document describing industrial use of the correlation. R. Mares discussed the work of the Evaluation Task Group, which has not yet finished evaluating the latest version. The following schedule was adopted for further processing of the viscosity release:

Jan. 31, 2007 Completion of evaluation by Evaluation Task Group
Feb. 28, 2007 Revision of draft release if required
Mar. 15, 2007 Evaluation report distributed to Working Group
Apr. 15, 2007 Deadline for input from WG members
Apr. 30, 2007 Finalized draft of Release to Editorial Committee
May 31, 2007 Approval by Editorial Committee and distribution to National Delegates
Mr. Miyagawa was added to the Evaluation Task Group for viscosity and Mr. Cooper withdrew from the TG.

9.2 W. Wagner presented material concerning the differences between the current scientific and industrial formulations for thermal conductivity, and the difficulties the current structure caused for users. D. Friend described the work toward a new thermal conductivity formulation. A complete database has been developed, along with a correlation for the dilute-gas contribution. The goal is to have a preliminary formulation available for our 2007 meeting, and to adopt a final version in 2008. More consideration is needed to decide what to do about industrial use of the thermal conductivity, but it was decided that no "interim" changes would be made to the current formulations.

10. [This item is reported in the IRS minutes.]

11. W. Wagner presented some editorial corrections needed to correct misprints (and update a reference) in the documents for IAPWS-95 and Advisory Note #1. These misprints do not affect the formulation itself. The Editorial Committee provided some improvement of the proposed wording. **The Working Groups TPWS and IRS approved these minor editorial revisions to the documents and recommended their approval by the EC.**

12. W. Wagner reported that he has prepared a CD with documentation of the experimental data that was used in the development of IAPWS-95. **It was decided to recommend to the EC that this information be placed on the IAPWS Website.**

13-16. [These items are reported in the IRS minutes.]

17. The Workshop on Seawater on Tuesday afternoon, was a joint effort of all 4 IAPWS Working Groups. We welcomed B. King from the University of Southamption, who is affiliated with the International Association for the Physical Science of the Oceans (IAPSO). R. Feistel presented an overview of IAPSO and its liaison activities with IAPWS. He described how IAPSO had decided to use IAPWS-95 as their pure-water baseline for a future formulation for the properties of seawater, and that extrapolation below 0 °C was still a question mark. B. King described current seawater property standards and discussed issues regarding conversion to the ITS-90 temperature scale and issues with the definition and scale for salinity. The need for a clearer physical definition of seawater was discussed. R. Feistel described work on new formulations for seawater properties, using IAPWS-95 as a baseline, and work on an extended formulation to cover a wider range of salinity. Material was presented on hydrothermal vents

which can involve water at supercritical conditions; it was pointed out that the composition of the vent fluids is very different than that of normal seawater. B. King briefly discussed measurement needs for the oceanographic community, which included not only thermodynamic properties but also optical properties (refractive index) for possible sensors.

R. Feistel presented a draft ICRN for seawater properties. Further discussion of this was deferred until the TPWS meeting.

The future of cooperation between IAPWS and IAPSO was briefly discussed. Liaison and email communication will continue, and attendance at the other organization's meetings will continue to be encouraged. **P. Tremaine is added to the existing IAPWS Task Group on seawater** (which also includes Feistel (Chair), Wagner, Harvey, and Hiegemann).

The WG returned Thursday to the proposed ICRN on seawater. **The WG recommends that the proposed ICRN be adopted, subject to editorial revisions.**

18. A joint session with PCAS was held on Thursday morning. The topics are listed in the attached Agenda (TPWS attachment A), except that there was no presentation from the Simulation Task Group.

The item requiring WG action was the proposed new release on the ionization constant of water. S. Lvov summarized the formulation and the proposed draft release. Several suggestions for improvement were agreed upon, including the addition of a table of check values, a clear definition of the Kw quantity, and a more complete statement of the uncertainty in various regions (possibly with the aid of a figure). **An Evaluation Task Group (joint between the 2 WGs) was appointed consisting of Harvey (Chair), Nakahara, Palmer, and Tremaine. The following schedule was adopted, anticipating final approval in 2007**:

Oct. 1, 2007 Draft Release (incorporating comments from this meeting) sent to Evaluation TG and WG members, with WG members invited to send comments to Evaluation TG.
Dec. 31, 2006 Completion of evaluation by Evaluation Task Group
Jan. 15, 2007 Evaluation report and revised release distributed to Working Group
Feb. 15, 2007 Deadline for input from WG members
Mar. 1, 2007 Finalized draft of Release to Editorial Committee
April 1, 2007 Approval by Editorial Committee
Apr. 15, 2007 Distribution by Executive Secretary to National Delegates

19. A. Harvey reported that no update was needed this year on the IAPWS Fundamental Constants document.

J. Cooper stated that there was nothing to report concerning liaison with the IEC.

A. Harvey reported that some progress had been made toward producing a joint document with the CCM to guide people about when to use their standard for water density for metrology, and when use of IAPWS-95 is appropriate. However, progress has been delayed due to concerns on the CCM side, which it is hoped can be addressed soon. It is hoped to have something completed before the next IAPWS meeting.

A. Harvey briefly presented some reasons why it might be useful for IAPWS to adopt simple equations for various properties of liquid water at standard atmospheric pressure. It was agreed that this would be useful. **A Task Group was appointed to work on this, consisting of Harvey (Chair), Hruby, and Kretzschmar. The WG Chair was authorized to appoint an Evaluation Committee during the year if work proceeded quickly enough for this to be appropriate.**

J. Cooper reported briefly on the status of heavy water. He pointed out the need to clarify the existence of a comprehensive data collection for future thermodynamic work. J. Sengers reported that the International Association for Transport Properties (IATP) was suspending work on heavy water for the moment. The Chair volunteered to ask the Canadian delegation about current interest in heavy water. **J. Cooper and J. Sengers will check the influence of the ITS-**

90 temperature scale on the current releases for heavy water transport properties, and if all goes well they will bring a proposal for a revised release to the 2007 meeting.

19.6. [This item is reported in the IRS minutes.]

20. **It was voted to accept M. Nakahara for membership in TPWS.** National committees are asked to check the status of inactive members in their home countries before next meeting.

21. For item 21.1, there were no collaborative projects to report on. Item 21.4 is in the IRS minutes. As additional other business, it was decided that the Chair would email TPWS presentations from the meeting to all members of the WG, and that the maintainer of the IAPWS website would be asked to investigate the possibility of putting these documents on the website in a way so that access could be restricted to members only.

21.2 **The WG requests that the EC authorize spending up to $3000 to pay page charges for the last 2 of the 4 papers describing supplementary "backward" equations, both of which will be submitted in the next year.**

21.3 **O. Sifner was appointed as the TPWS representative to the Gibbs award committee.**

22. The Chair and Clerk of Minutes were appointed to prepare the formal motion of the TPWS WG to the EC.

23. The meeting was adjourned at 4:50 PM on Thursday, September 7.

Agenda

IAPWS THERMOPHYSICAL PROPERTIES OF WATER AND STEAM WG
WITNEY, UK,

SEPTEMBER 3-8, 2006

1. Opening Remarks; Adoption of Agenda
2. Appointment of Clerk of Minutes
3. Approval of Minutes of TPWS WG in Santorini, Greece (July 2005)
4. Potential International Collaborative Projects
5. Release on Ice, joint with WG IRS
   - Report of the Evaluation Committee (J. Hruby and A.H. Harvey)
   - Formal Consideration of the Release by the WGs TPWS and IRS
6. Development of New Equations for Melting Pressure and Sublimation Pressure (R. Feistel)
7. Possibility for Improvement of Ideal-gas Partition Function and Heat Capacity of Water, Especially at Low Temperatures (R. Feistel and A.H. Harvey).
8. Development of a New Basic Equation for Region 5 of IAPWS-IF97 for Pressures up to 50 MPa, joint with WG IRS
   - Proposal for a Revised Release (W. Wagner)
   - Appointment of an Evaluation Task Group
9. Transport Properties of Water and Steam, joint with WG IRS
   9.1 Viscosity
   - Report of the Task Group (J.V. Sengers)
   - Report of the Evaluation Task Group (R. Mares)

   9.2 Thermal Conductivity
   - Statement on the Differences Between the Equations for Thermal Conductivity for Industrial and Scientific Use (W. Wagner)
   - Report of the Task Group (D.G. Friend)
10. Advisory Note No. 3 on Thermodynamic Derivatives from IAPWS Formulations (H.-J. Kretzschmar), joint with WG IRS
    - Appointment of an Evaluation Task Group
11. Editorial Corrections to IAPWS-95 Release Document and Advisory Note No. 1 (W. Wagner)
12. CD with Experimental Data the IAPWS-95 Formulation is Based on (W. Wagner)

13. Computing Time Investigations of the IAPWS-IF97 Backward Equations, joint with WG IRS

14. Calculation of the Dissociation of Steam - Guidance for Users of the IAPWS Formulations (J. Bellows), joint with WG IRS

15. Requirements on Properties for Working Fluids, joint with WG IRS
    - Power Cycles with CO_2 Sequestration (R. Span)
    - Requests for New Equations of Working Fluids from Industrial Point of View - Environmental Issues Task Group Report (Environmental Task Group, N. Okita)

16. "Steam Tables on Pocket Calculators" for Students Available on the IAPWS Website (H.-J. Kretzschmar, A.H. Harvey, B. Rukes), joint with WG IRS

17. Workshop on Properties of Seawater (R. Feistel), joint with WGs IRS, PCAS, PCC (Tuesday Afternoon)
    - A Brief History and Current Activities of the International Association for the Physical Science of the Oceans (IAPSO) (R. Feistel)
    - Liaison with IAPSO, Letters Between the IAPWS President and the President of IAPSO (R. Feistel)
    - Oceanographic Seawater Standards (B. King, R. Feistel)
    - Unit for the Salinity of Seawater, Conflict with ISO (B. King)
    - Development of an Extended Formulation of the Thermodynamic Properties of Seawater (R. Feistel)
    - Physical Chemistry of Vents, Critical Properties (R. Feistel)
    - Request for Measurements/Instruments (B. King)
    - Formulation of an ICRN on Thermodynamic Properties of Seawater (R. Feistel)
    - Future Cooperation between IAPWS and IAPSO (R. Feistel, B. King)

18. Joint Meeting with PCAS (Thursday Morning)
    - 18.1 Release on the Ionization Constant of Water (S.N. Lvov)
      - Appointment of an Evaluation Task Group
    - 18.2 Binary Nucleation of Steam with Admixtures Relevant in Power Industry and Atmosphere (T. Němec, F. Maršík, D. Palmer)
    - 18.3 Report of the Simulation Task Group (I.M. Svishchev, K. Yasuoka)
    - 18.4 Thermochemical Cycles for Hydrogen Production (S. Lvov)

19. Reports on Other TPWS Activities
    - 19.1 Fundamental Constants (A.H. Harvey)
    - 19.2 Liaison with IEC (J. Cooper), joint with WG IRS
    - 19.3 Liaison with CCM (A.H. Harvey, R. Span)

19.4 Discussion of Need for Equations for Properties of Liquid Water at Standard Atmospheric Pressure (A.H. Harvey)

19.5 Thermophysical Properties of Heavy Water

19.6 Dewpoint Data in Exhaust Gas, joint with WG IRS
- Measurement of Data status (E. Maughan)
- ICRN status (N. Okita)

20. Membership

21. Other Business

21.1 Report on International Collaborative Projects

21.2 Page Charges for Publication of Archival Papers on Supplementary Backward Equations for IAPWS-IF97

21.3 Gibbs Award Committee

21.4 Topics for the 15th ICPWS 2008 in Berlin

22. Preparation of the Formal Motion to the EC

23. Adjournment

REPORT TO THE IAPWS EXECUTIVE COMMITTEE ON 08 SEPT. 2006, WITNEY, UK

Witney Committee "Future Cooperation of IAPWS with the SCOR/IAPSO WG127"
(R. Feistel, H.-J. Kretzschmar and J.R. Cooper)

- The IAPWS Task Group on the Properties of Seawater consisting of R. Feistel (chair), A.H. Harvey, J.R. Cooper, M. Hiegemann and W. Wagner works together with the WG 127 of IAPSO.
- P. Tremaine will be a new member of the IAPWS Task Group on Seawater. He will be proposed to become a corresponding member of WG 127.
- IAPWS-95 experimental background data will be provided to WG127 by W. Wagner with a general permission for its use in oceanographic research.
- The existing IAPWS-95 computation source code will be provided to WG127 by W. Wagner with a general permission for its use in oceanographic research.
- A task group for the investigation of IAPWS-95 properties between the freezing points of pure water and of seawater will be established. At given pressure, the range of freezing temperature lowering due to dissolved salt is between 0 and 8 K. A report on the usability of IAPWS-95 as the pure-water reference for the Gibbs function of seawater in this range will be prepared.
  R. Feistel, W. Wagner, M. Anisimov are proposed to participate in this TG.
- The possibility of a modification of the IAPWS-95 computation source code with regard to a relaxation of its low-temperature application limit will be considered by W. Wagner.
- The IAPWS 2006 Release on Ice, consistently extending IAPWS-95 to the solid phase, will be provided as a new standard description usable for the determination of seawater freezing points.
- IAPWS will evaluate the new Gibbs function of seawater valid between 0 and 100 MPa, –17 and +40°C, 0 and 110 g/kg, planned for 2007, to be developed by R. Feistel.
- The IAPWS task group "Seawater" will continue its activity with the members R. Feistel (chair), A. H. Harvey, M. Hiegemann, P. Tremaine
- R. Feistel, appointed as the IAPWS liaison, will report to WG127 about the Witney meeting.
- IAPWS adopts a Certified Research Need (ICRN) on seawater properties over the parameter ranges of interest for industry and oceanography
- P. Tremaine will consider possibilities for measuring standard seawater properties at elevated pressures, in particular density and electrical conductivity
- R. Feistel will examine the conditions required for extending the planned Gibbs function to temperatures higher than 40°C at normal pressure. This range is of particular interest for power station cooling and desalination.
- It is recommended that the IAPWS 2007 meeting considers a suitable form of a repeated seawater workshop and the invitation of one ore more members of the WG127, e.g. the specialists in seawater chemistry, F. J. Millero (RSMAS, USA), A. C.-T. Chen (NSYSU, Taiwan), P. Spitzer (PTB, Germany), or G. M. Marion (DRI, USA).

- The ICPWS 2008 Organizing Committee will consider the IAPWS interest a specific seawater topic and will, in case, offer to WG127 the participation of oceanographers. A particular aspect of interest may be the relevance of the IAPWS work for climate research.

A reply letter from IAPWS to WG127 will be formulated by H. J. Kretzschmar, A.H. Harvey and R. Feistel regarding the topics reported above, including the minutes of the Witney meeting.