MINUTES OF MEETING OF WORKING GROUP INDUSTRIAL REQUIREMENTS & SOLUTIONS (IRS)

Witney, UK, 3. – 8. September 2006

Remark: The IRS minutes cover the topics chaired by the IRS working group chairman. All other agenda topics of joint meetings are covered in the TPWS working group minutes.

1. **Opening remarks, Adoption of Agenda**
   Chairman B. Parry welcomed the WG members to Witney. The agenda was adopted with slight adjustments (Attachment A to IRS Minutes)

2. **Appointment of Clerk of Minutes**
   I. Weber was appointed clerk of minutes.

3. **Approval of Santorini Meeting Minutes**
   The minutes of the 2005 IRS WG meeting were approved unchanged.

4. **Potential International Collaborative Projects**
   There were no proposals for International Collaborative Projects from IRS.

5. **Release on Ice**
   See TPWS minutes.

6. **Development of New Equations for Melting Pressure and Sublimation Pressure**
   See TPWS minutes.

7. **Possibility for Improvement of Water's Ideal-gas Partition Function and Heat Capacity especially at Low Temperatures**
   See TPWS minutes.

8. **Development of a New Basic Equation for Region 5 of IAPWS-IF97 for Pressures up to 50 MPa**
   W. Wagner presented the proposal of a new basic equation for region 5 of IAPWS-IF97 for pressures up to 50 MPa:
   - Ideal gas part of original equation remains unchanged.
   - Number of term for residual part of the equation is increased from 5 to 6.
   - Original equation has better consistency with the basic equation of region 2 of IAPWS-IF97, however the consistency requirements are also met by the proposed new equation.

   W. Wagner additionally presented a draft of a revised release of the IAPWS-IF97 release. This draft contained changes necessary due to the new equation for region 5 as well as minor editorial corrections.
   Extensive discussion developed regarding the impact of the new development. Two major directions established during the discussion:
   - Amend the existing release on IAPWS-IF97 but being careful regarding the naming in order to minimize the impact on the user base.
   - Keep the existing release on IAPWS-IF97 unchanged but create a supplementary release solely dealing with the new equation for region 5.

No final conclusion could be found on this topic. An ad-hoc committee consisting of N. Okita, B. Parry and B. Rukes was established to make a suggestion on how to handle this issue. They were requested to report back on Thursday.
An evaluation task group will be set up to technically evaluate the proposed new equation; B. Parry will contact K. Miyagawa in order to form this task group.

Revisited on Thursday, 7. September 2006:
The ad-hoc task group recommends a revised release on IAPWS-IF97. Additionally a subtitle "The revision only relates to the extension of region 5 up to 50MPa" should be added. Discussion developed about this topic, the consensus is that it should be called a "revised release" and that the editorial committee develops a proper wording for the subheading making clear that the previous region 5 equation has been replaced by the revised equation. The WGs will recommend this procedure to the EC. Additionally the WGs will recommend to the EC that individual national committees contact their industrial representatives for their opinion on revising IFC-97. Any feedback should be channeled to the IRS WG Chairman by 31 December 2006.
H.-J. Kretzschmar reported that he had contacted K. Miyagawa concerning his participation on the evaluation task group for revised region 5. K. Miyagawa expressed his willingness to chair the evaluation task group. R. Mares volunteered to participate on the task group. Therefore, the evaluation task group will consist of R. Mares and K. Miyagawa; Mr. Miyagawa will be the chairman.
The working groups suggest the following schedule:

2006-12-31: completion of evaluation
2007-01-15: evaluation report to working groups
2007-02-15: deadline for input by the working group members
2007-03-01: evaluation report to editorial committee
2007-04-01: approval by the editorial committee and handover to Executive Secretary
2007-04-15: Executive Secretary distributes to National Committees

K. Miyagawa has agreed to this schedule.

9. Transport Properties of Water and Steam

See TPWS minutes.

10. Advisory Note No. 3 on Thermodynamic Derivatives from IAPWS Formulations

H.-J. Kretzschmar presented a draft for an advisory note no. 3 on thermodynamic derivatives from IAPWS formulations. The draft is based on the presentation given at the IAPWS meeting 2005 in Santorini but extended by guidance for the cases heavy water and ice. H.-J. Kretzschmar has contacted K. Miyagawa prior to the meeting and he is willing to chair an evaluation task group. The task of the evaluation task group is to verify the formulas stated in the advisory note.
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2007-03-01: evaluation report to editorial committee
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2007-04-15: Executive Secretary distributes to National Committees
This schedule requires approval by K. Miyagawa in order to be effective.

11. Editorial Corrections to IAPWS-95 Release Document and Advisory Note No. 1
See TPWS minutes.

12. CD with Experimental Data which form the basis of IAPWS-95 Formulation
See TPWS minutes.

13. Computing Time Investigations of the IAPWS-IF97 Backward Equations
Since K. Miyagawa was not able to attend the meeting H.-J. Kretzschmar presented the results of the computing time investigations. The report is to a large extent based on the material presented 2005 in Santorini. In addition to the previous information also the effects of using the IAPWS-IF97 backward equation as starting point for high accuracy iterative calculations of the IAPWS-IF97 fundamental equations were investigated. Using the backward equation as starting point increases the calculation speed roughly by a factor of 2. This also holds for calculations with IAPWS-95, the speed increase is even somewhat higher in this case.
Meanwhile a paper on this topic has been submitted to the ASME Journal of Engineering for Gas Turbines and Power.

14. Calculation of the Dissociation of Steam - Guidance for Users of the IAPWS
J. Bellows gave a short verbal presentation on the question of dissociation of steam. He pointed out that all steam property formulations describe the properties of H2O molecules but that there is no model available for the dissociated case or steam with oxygen or hydrogen excess. A first approximation would be to consider an ideal mixture with equilibrium conditions. However the question remains how ideal these mixtures really are. Additionally cases which involve kinetics would have to be considered. Possible questions for steam dissociation could be:

- Amount of dissociated matter
- Changes in properties due to dissociation

Chairman B. Parry pointed out that as long as there is no defined request from industry IAPWS would not become active in this field.

15. Requirements on Properties for Working Fluids

a. Power Cycles with CO2 Sequestration
R. Span gave a presentation on power cycles with CO2 capture and CO2 transportation and storage. He gave an overview about different storage options as well as about the status of projects, i.e. demonstration plants and plans for commercial plants. He presented different approaches for CO2 capturing and went to somewhat more detail for the so called oxyfuel processes where combustion takes place with pure oxygen. Combustion products are mainly CO2 and H2O, i.e. a proper model for the properties of this mixture is required. Not only non-ideal behavior at various conditions has to be covered but also phase equilibria, e.g. for the separation of CO2 by means of H2O condensation. Even additional constituents like N2, Ar, O2, CO, NOx and unburned hydrocarbons may have to be considered depending on the application. Additional requirements emerge from the areas of CO2 compression, transportation and storage. Apparently there is a strong need of accurate data and accurate models but also better interaction is required with the geology / oceanography community to share knowledge and ideas.
During the discussion W. Wagner pointed out that a model exists which is capable of producing property data for the discussed mixture. This model

currently includes 18 constituents and is based on the property data of binary mixtures, however property data for more complex mixtures can be produced almost as good as the experimental uncertainties.

Revisited on Thursday, 7. September 2006:
R. Span pointed out that there is a requirement to fund further research however this cannot come from IAPWS. Therefore he suggests to revise the existing ICRN on humid air and combustion gases to cover also the liquid phases. He agreed to prepare a draft for an updated ICRN to be presented in 2007.

b. Requests for New Equations of Working Fluids from Industrial Point of View

N. Okita gave a presentation on the industrial requirements for new equations of working fluids. He gave a summary of the work of the environmental task group which has been presented in 2005. The areas CO2 capture and humid combustion gases were addressed before and work is continuing. However another area of urgent need for further investigations is the dew point in combustion gases. There is knowledge about the dew point in air however for combustion gases there is not sufficient data available. From industrial point of view the condensation of sulfuric acid presents sever corrosion issues. Currently industry applies high design margins to cover the impact however better knowledge could help to reduce these margins and therefore power plant efficiencies. He summarizes that there is a need for accurate data and formulation for the dew point of combustion gases. Discussion continued under item 17. b.

16. "Steam Tables on Pocket Calculators" for Students Available on the IAPWS Website

At the 2005 Santorini meeting it was decided to make the "Steam Tables on Pocket Calculators" available on the IAPWS website. H.-J. Kretzschmar gave an update on the status:
The German National Committee verified and accepted the download pages for the pocket calculator steam tables. Since then a link from the IAPWS website to these download pages is active. H.-J. Kretzschmar gave a short online presentation of the download pages. He also expressed that the location of the link is somewhat concealed and some discussion developed on how to better present this type of information. Since this is part of the "educational and outreach" efforts it was suggested to add a main topic "educational resources" to the IAPWS website which could contain e.g. all the links to available software.

17. Dew Point Data in Exhaust Gas

a. Measurement of data status

E. Maughan gave a presentation on the theory of humidity and dew point measurement techniques. The dew point is defined to be the temperature for given pressure where condensation of some liquid matter occurs. He pointed out that the dew point depends on the composition of the gas and additionally that the condensate may possibly be corrosive.

b. ICRN status

N. Okita proposes to prepare an ICRN on the dew point in combustion gases. During the discussion R. Span pointed out that the existing ICRN on humid air

and combustion gases does not cover this issue. Extensive discussion developed about the proposed ICRN. There was concern that it will be very difficult to realize (due to measurement uncertainties for SO_2 and SO_3, liquid formation processes, exact definition of dew point, etc.). It was suggested to first evaluate the existing equations and based on this the need for further equations and research could be derived. Apparently PCC will propose an ICRN on a similar topic, there should be some discussion to reach a common position.
A task group on evaluation of this issue was formed consisting of N. Okita, R. Span and J. Hruby, chaired by N. Okita. The task group is requested to present its findings in 2007 and also contact PCC on this issue.

18. Workshop on Properties of Seawater

See TPWS minutes.

19. Appointment of IRS WG member to serve on Gibbs Award Committee

B. Rukes agreed to serve as a member of the Gibbs Award Committee. If he is unable to serve, Roland Span agreed to serve in this capacity.

20. Membership

There were no membership items to be discussed this year.

21. Other Business

a. Topics for 15th ICPWS 2008
The WGs discussed the list of topics suggested by the German Organizing Committee and made some comments.

22. Preparation of Report to Executive Committee

The Chairman and Clerk of Minutes will prepare the report to the EC.

23. Adjournment

The Chairman adjourned the meeting of the IRS working group at 7. September 2006, 3:30pm.

Agenda
of
Industrial Requirement and Solutions Working Group

WITNEY, UK, 3 TO 8 SEPTEMBER 2006

1. Opening Remarks, Adoption of Agenda
2. Appointment of Clerk of Minutes
3. Approval of Minutes of Meeting, IRS WG in Santorini, Greece (July 2005)
4. Potential International Collaborative Projects
5. Release on Ice, joint with WG TPWS
   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 Water's Ideal-gas Partition Function and Heat Capacity 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 TPWS
   -- Proposal for a Revised Release (W. Wagner)
   -- Appointment of an Evaluation Task Group
9. Transport Properties of Water and Steam, joint with WG TPWS
   9.1 Viscosity
   - Report of the Task Group (J.V. Sengers)
   - Report of the Evaluation Task Group (R. Mares)

   9.2 Thermal Conductivity
   - Report of the Task Group (D.G. Friend)
   - Statement on the Differences Between the Equations for Thermal Conductivity for Industrial and Scientific Use (W. Wagner)
10. Advisory Note No. 3 on Thermodynamic Derivatives from IAPWS Formulations (H.-J. Kretzschmar), joint with WG TPWS
11. Editorial Corrections to IAPWS-95 Release Document and Advisory Note No. 1 (W. Wagner), joint with WG TPWS
12. CD with Experimental Data which form the basis of IAPWS-95 Formulation (W.Wagner), joint with WG TPWS
    13.Computing Time Investigations of the IAPWS-IF97 Backward Equations, joint with WG TPWS
14. Calculation of the Dissociation of Steam - Guidance for Users of the IAPWS Formulations (J. Bellows), joint with WG TPWS
15. Requirements on Properties for Working Fluids, joint with WG TPWS
    - 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 (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 TPWS
17. Dewpoint Data in Exhaust Gas – joint with WG TPWS
    Measurement of Data status (Eric Maughan)
    ICRN status (N. Okita)
18. Workshop on Properties of Seawater (R. Feistel) – joint with WGs TPWS, PCAS, & PCC
19. Appointment of IRS WG member to serve on Gibbs Award Committee
20. Membership
21. Other Business
22. Preparation of Report to Executive Committee
23. Adjournment