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CURRENT IAPWS RELEASES AND SUPPLEMENTARY RELEASES (September 2003)

- Supplementary Release: “Backwards Equations for the Functions *T(p,h), v(p,h)* and *T(p,s), v(p,s)* for the Region 3 of the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam”. (August 2003).

- “Revised Release on the IAPS Formulation 1985 for the Viscosity of Ordinary Water Substance”. (August 2003). (This release is a revision of the corresponding release of 1997, which replaced the original release of 1985).

- Supplementary Release: “Backwards Equations for Pressure as a Function of Enthalpy and Entropy *p*(*h,s*) to the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam”. (September 2001).

- Revised Release: "IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substances". (September 1998). (This release replaces the corresponding release of November 1985).

- “Release on the Refractive Index of Ordinary Water Substance as a Function of Wavelength, Temperature and Pressure.” (September 1997) (This release replaces the corresponding release of 1991).

- “Release on the Static Dielectric Constant of Ordinary Water Substance for Temperatures from 238 K to 873 K and Pressures up to 1000 MPa.”. (September 1997). (This release replaces the corresponding release of 1977).

- “Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam.” IAPWS –IF 97. (September 1997) (This release replaces the 1967 IFC Formulation for Industrial Use).

- “Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use.” (September 1996) (This release replaces the corresponding release of 1984).

- Release: "IAPWS Skeleton Tables 1985 for the Thermodynamic Properties of Ordinary Water Substance". (September 1994). (This is a revision of the 1985 Release).

- Release: "Surface Tension of Heavy Water Substance ". (September 1994). (This is a revision of the 1985 Release).

- Release: "Surface Tension of Ordinary Water Substance". (September 1994). (This is a revision of the 1976 Release).

- "Release on the Pressure along the Melting and Sublimation Curves of Ordinary Water Substance". (September 1993). (This is a revision of the 1989 Release).

- IAPS Supplementary Release: "Saturation Properties of Ordinary Water Substance". (September 1992). (This is a revision of the 1986 Release).

- Release: "Values of Temperature, Pressure and Density of Ordinary and Heavy Water Substances at their Respective Critical Points". (September 1992) (This is a revision of the 1983 Release).

- Release: "IAPS Formulation 1984 for the Thermodynamic Properties of Heavy Water Substance". (September 1984).

- Release: "Viscosity and Thermal Conductivity of Heavy Water Substance". (September 1982. Revised February 1984).

- Release: "Ion Product of Water Substance". (May 1980).

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CURRENT IAPWS GUIDELINES (September 2003)

- Guideline: "Tabular Taylor Series Expansion (TTSE) Method for Calculation of Thermodynamic Properties of Water and Steam Applied to IAPWS-95 as an Example". (August 2003).
- Guideline: "The Use of Fundamental Physical Constants and Basic Constants of Water". (September 2001).
- Guideline: "IAPWS Formulation 2001 for the Thermodynamic Properties of Ammonia-Water Mixtures". (September 2001).
- Guideline: "The Critical Locus of Aqueous Solutions of Sodium Chloride". (September 2000).
- Guideline: "Equilibrium Constant for the Distribution of Gaseous Solutes between Steam and Water". (September 1998)
- Guideline: "Equilibrium Constant for the Distribution of Gaseous Solutes between Steam and Water". (September 1998).
- Guideline: "Solubility of Sodium Sulfate in Aqueous Mixtures of Sodium Chloride and Sulfuric Acid from Water to Concentrated Solutions, from 250^{o}C to 350^{o}C". (September 1994). (This is a revision of the 1990 Guideline).
- Guideline: Solution of Simple Apolar Gases in Light and Heavy Water at High Temperature. (September 1993).
- Guideline: "Electrolytic Conductivity (Specific Conductance) of Liquid and Dense Supercritical Water from 0oC to 800^{o}C and Pressures up to 1000 MPa". (May 1990).

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CURRENT IAPWS ADVISORY NOTES (September 2003)

- Advisory Note No. 1: “Uncertainties in Enthalpy for the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use (IAPWS-95) and the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (IAPWS-IF97)”. (August 2003).

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IAPWS CERTIFIED RESEARCH NEEDS (ICRNS) (AUGUST 2003)

1. Evaluation of Binary Nucleation Models. Issued September 1993. Needs Revision to extend to September 2004. IAPWS Contact: F. Sigon.

2. Solubility of Sodium Sulphate in Superheated Steam. Issued September 1993. Expired September 2001. IAPWS Contact: K. Daucik. Closing Statement, October 2001.

3. Solubility of Spinels in the Chemical Conditions of Nuclear Reactors. September 1993. Issued September 1993. Expired September 1996.
Closing statement prepared. IAPWS Contacts: D. You.

4. Interaction Between Sodium Salts (Phosphates, Sulfates, Silicates, Borates) and Transition Metal Oxides. Issued September 1993. Closed September 1996. IAPWS Contact: J. Stodola.

5. Origin, Behaviour, and Fate of Organics in the Power Cycle. Issued September 1993. Needs Revision to extend to September 2004. IAPWS Contact: R. Gilbert.

6. Thermophysical Properties of Ammonia-Water Mixtures. Issued June 1994. Closed September 2002. IAPWS Contact: W. Parry. Closing Statement, July 2002.

7. Carryover Coefficients of Salts and Metal Contaminants in Boiler Water. Issued June 1994. Expired June 1997. Closed September 1999. IAPWS Contact: P. Tremaine.

8. Development of an Accurate External Reference Electrode for Use in High Temperature and High Pressure Aqueous Solutions. Issued August 1994. Expired August 1997. Closed September 1998. IAPWS Contact: S. Lvov.

9. Thermodynamic Models for Transition-Metal/Water Systems under Steam Generator Conditions. Issued September 1994. Closed September 2000. IAPWS Contact: P. Tremaine

10. pH Measurements and Potentiometric Studies of Supercritical Aqueous Solutions. Issued May 1996. Extended to September 2002. IAPWS Contact: S. Lvov.

11. Properties of Salts in Steam. Issued May 1996. Closed September 2001. IAPWS Contacts: D. Palmer and R. Fernandez-Prini. Needs Closing Statement.

12. Kinetics of the Oxygen and Hydrogen Electrode Reactions in Subcritical and Supercritical Aqueous Systems. Issued September 1998. Closed September 2001. IAPWS Contacts: S. Lvov and D. Macdonald. Needs Closing Statement.

13. Surface Tension of Aqueous Solutions. Issued September 1998. Needs Revision to extend to September 2004. IAPWS Contacts: F. Sigon and F. Gabrielli.

14. Thermophysical Properties of Humid Air and Combustion-Gas Mixtures. Issued July 2002. Expires September 2005. IAPWS Contacts R. Span and F.L. Blangetti.

15. Thermodynamic Properties of Metastable Steam. Issued July 2002.Expires September 2005. IAPWS Contact: B. Rukes.

Attachment 10

IAPWS Collaborative Grant Proposal

An experimental study of *PVTx* properties for the system ammonia + water at high temperatures and pressures

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This proposal will have four principal outcomes: it will strengthen collaborations between the Thermophysical Division of the Dagestan Scientific Center of the Russian Academy of Sciences (DSC RAS) and the National Institute of Standards and Technology (NIST) in the US; it will enable a young scientist to travel from the DSC RAS to NIST for training in best practices for calibrations, measurements and data evaluation; it will provide the IAPWS community with new measurements of *PVTx* properties for the aqueous system ammonia + water in wide ranges of temperature and pressure, including near-critical and supercritical regions; and, it will initiate a broad program of measurements and models for the ammonia + water system.

An IAPWS Certified Research Need [1] indicated a need for properties for ammonia + water mixtures at temperatures to 866 K (593^{o}C) at pressures up to 35 MPa, covering the complete range of composition. In spite of research activity from 1997 to 2002 that was reported in the Closure Statement for this ICRN, data are still very limited in high-temperature regions for ammonia + water mixtures.

The primary reasons for the scarcity of data are experimental difficulties related to the fact that this system is corrosive, toxic, potentially flammable, and has a high relative volatility. Special materials, safety procedures, special equipment and a knowledge of their proper use are all required. Only a handful of labs, including NIST, have been able to make sufficient investment in training and materials to make such measurements.

Accurate *PVTx* data are essential to the development of an accurate equation of state. New experimental data are particularly needed [2] at temperatures $T > 523$ K, which is the present upper limit of reported measurements. Both the Physical and Chemical Properties Division of NIST and DSC RAS have extensive experience and capabilities in accurate *PVTx* measurements covering wide ranges of temperature and pressure. We have reported [3-6] *PVTx* data for aqueous systems (H_2O + alcohol, H_2O + hydrocarbon, and H_2O + D_2O) in the near-critical and supercritical regions. For reasons mentioned earlier, the labs of DSC RAS and NIST are among the few research facilities in the world with capabilities for H_2O + ammonia *PVTx* measurements in the near-critical and supercritical regions, as documented at a Workshop on Properties of H_2O + Ammonia [7].

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Under other funding, Prof. Abdulagatov's team in the Dagestan Labs will investigate *PVTx* properties in a temperature range from 300 to 673 K (27 to 400°C) at pressures up to 35 MPa. The measurements will be for a fixed composition of 0.5 mole fraction ammonia, with an uncertainty in density of 0.1 %. This investigation will provide reliable *PVTx* properties by using a high-temperature and high-pressure constant-volume piezometer [3-6].

Following the experiments, we plan to bring a younger Dagestan Labs scientist to the Boulder Labs of NIST for 3 to 4 months. Dr. Emil Bazaev will be our top choice, since his PhD was granted in 2000 for a dissertation on *PVTx* properties. Dr. Bazaev will assist Joseph Magee and his team in the Boulder Labs with the following tasks: (1) additional *PVTx* measurements with a high-temperature corrosion-resistant direct-weighing *PVTx* apparatus [8], at temperatures up to 1000 K; (2) analysis of the *PVTx* data; and, (3) comparison with published measurements and models, especially the IAPWS Formulation 2001 for the Thermodynamic Properties of Ammonia-Water Mixtures. As an additional educational component of his visit, we will conduct detailed discussions and comparisons of the experimental *PVTx* techniques used in the Dagestan Labs with those used in the Boulder Labs (isochoric gas expansion, direct-weighing isochoric, vibrating-tube densimeter and dual-sinker densimeter), methods for precise gravimetric mixture preparation, a propagation of uncertainties analysis, round-robin measurement comparisons, and establishing a chain of traceability to national and international standards.

The proposed *PVTx* measurements for IAPWS are to be carried out on a 0.5 mole fraction ammonia + 0.5 mole fraction water mixture at the conditions:

- Temperatures from 373 K to 673 K
- Pressures from 0.1 MPa to 50 MPa
- Measurements will be carried out in the liquid phase, vapor phase, and the supercritical fluid regions of the mixture.

The measurements will be compared to other experimental densities and all will be compared with the formulation in the current IAPWS Guideline.

Other funding will be sought for additional gas-phase *PVTx* measurements in a new apparatus, from 373 K to 1000 K, at pressures from 0.1 MPa to 20 MPa, and also specific heat, viscosity, and thermal conductivity.

Budget

We propose a total budget of $10,000 for this project and a period of performance of one year. This would pay for the travel expenses and visit for Dr. Emil Bazaev or other young DSC RAS scientist for his work in Boulder with the US-based research team. A project report will be prepared and submitted to IAPWS by the next annual meeting.

Leveraging of the IAPWS Support

The research team has planned a comprehensive research project on the ammonia + water system, involving partnerships with university-based researchers. To leverage the support from IAPWS, we will seek additional support from other agencies. Toward the end of the proposed one-year IAPWS project, one or more proposals will be prepared to support the following tasks: (1) additional measurements of thermodynamic properties (a) *PVTx* data for two other compositions of the ammonia + water system and (b) C_V data with a constant-volume adiabatic calorimeter (Dagestan) at temperatures to 673 K; (2) measurements of transport properties (a) viscosity with a new oscillating-wire viscometer (Boulder), for which new high-temperature electrical feeds have been developed and (b) thermal conductivity with a tantalum transient hot-wire apparatus (Boulder); (3) development of new models for (a) thermodynamic properties − a Helmholtz fundamental equation and a crossover model for the critical region and (b) for transport properties − viscosity and thermal conductivity.

References

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5. Abdulagatov, I.M., Bazaev, E.A., Bazaev, A.R., Rabezkii, M.G. PVTx Measurements for Dilute Water+N-Hexane Mixtures in the Near-critical and Supercritical Regions. J. of Supercritical Fluids. 2001. V.**19**. P.219-237.
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