Attachment 7

MINUTES OF INDUSTRIAL CALCULATIONS WORKING GROUP

Joint meeting of TPWS and IC was opened by TPWS chairman Daniel Friend at 11:33 on September 10th, 2001. After chairman Friend had conducted the initial TPWS business, IC chairman Kiyoshi Miyagawa conducted opening business for the Industrial Calculations working group.

Item #1 – Approval of Agenda – chairman Miyagawa described the proposed agenda for the week. The agenda is documented in IC Attachment A and was approved without dissent.

Item #2 – Appointment of Clerk – chairman Miyagawa appointed William Parry to act as clerk of the minutes.

Item #3 – Approval of IC Minutes from Prague – Minutes were accepted without dissent.

Dan Friend acted as the chair for the Joint TPWS / IC session.

Item #4 – Dr. Friend asked Mr. Miyagawa to present the Test Report on the proposed Supplementary Release on Backward Equations for Pressure as a function of Enthalpy and Entropy [**p(h,s)**]. Mr. Miyagawa briefly reviewed the history of this proposed supplementary release. The requirements were induced from the IAPWS-IF97 specification for the backward equations. The Task Group consisting of Mr. Miyagawa and Dr. John Gallagher verified the accuracy of the p(h,s) function in terms of:

a) Numerical consistency with IAPWS-IF97 – Tables 4 and 10
b) Consistency at Subregional Boundaries within Region 2
c) Correctness of Verification Tables 3 and 9.

The inferred function T(h,s) = T(p(h,s),h) was also confirmed for accuracy against Table 11 and at the Subregional Boundaries. Computing time was evaluated versus a two dimensional Newton method. The two dimensional Newton method iteration took 23 times as long to run in Region 1, and 38 times longer than the proposed p(h,s) function in Region 2. The Task Group recommended that the Supplementary Release for p(h,s) be adopted as an IAPWS product and that the Proposer's code be treated as part of the IAPWS-IF97 code. Discussion ensued about the wording of the recommendation. Dr. Jan Sengers made a motion and seconded by Dr. Bert Rukes that the draft of the Supplementary Release on the backward equation p(h,s) should be adopted as an IAPWS Supplementary Release. A raise of hands indicated no objection from any member. A second motion made by Dr. Allan Harvey and seconded by Professor Koichi Watanabe stated that "the proposer's code for p(h,s) should be given to each National Committee as a supplement to the IAPWS-IF97 code. A show of hands indicated no objection. After much discussion, a third motion was made that "when the executive secretary is requested to provide a copy of the IAPWS-IF97, the secretary will also include a copy of the p(h,s) supplementary release. In addition, the IAPWS website will automatically link

the original IAPWS-IF97 release with the p(h,s) Supplementary Release." This was accepted without dissent. Professor Kretzschmar thanked the Task Group for their excellent evaluation work. Chairman Friend asked that both Professor Kretzschmar and the Evaluation Task Group be applauded for their efforts.

Item #5 – Mr. Ingo Weber presented the Progress Report of the Evaluation Task Group for the Guideline on the Tabular Taylor Series Expansion (TTSE) Method. Two different approaches were used in the evaluation: theoretical testing and practical testing. In the theoretical testing, direct comparisons were made between function calls v(p,T), h(p,T), and s(p,T) using IAPWS-IF97 method, and the TTSE method using tables derived from the corresponding IAPWS method. High accuracy was obtained except in areas close to the critical point. Numerical consistency was checked by comparisons of T(p,h) versus h(p,T) and T(p,s) versus s(p,T). Numerical consistency was very good for the former comparison, with some small inconsistencies (0.025 K) for the latter. Speed was comparable to IAPWS-IF97. For the practical tests, comparisons were made between IAPWS-IF97 and TTSE using that formulation. In heat balance calculations, the overall heat rate was very close to the same between the two methods; there was a larger deviation in outlet enthalpy at the condensate pumps probably due to some inaccuracy in s(p,h) at the lower values of p and h in this area. Calculation speed was about 10% faster with TTSE. For a transient simulation program using density and enthalpy as the main variables, no detectable difference seen between the two methods, but the computing time of IAPWS-IF97 was 4 to 3 times longer than the TTSE method. In a Heat Recovery Steam Generator (HRSG) simulation, the differences seen were negligible. The overall conclusion is that there was no speed or accuracy advantage for the TTSE method compared to IAPWS-IF97, but there would be a significant advantage over IAPWS-IF97 routines with special pair of independent variables, such as density and enthalpy, or IAPWS-95 in terms of speed.

A discussion ensued about the ultimate goal of the method which carried over to the next day. The following items were resolved:

1) The working title for the guideline describing the TTSE method would be "Documentation and Software of TTSE Method applied to IAPWS-95 as an example".
2) Maximum Pressure in range of validity = 100 MPa, 4000 kJ/kg.
3) For example using IAPWS-95, meet tolerances of IAPWS-IF97.
4) Computational Speed – about 100 times faster than IAPWS-95
5) Forward Functions – T(p,h), v(p,h), s(p,h)
6) Inverse Functions – h(p,T), h(p,s)
7) Metastable Region
   Liquid based on IAPWS-95
   Vapor – Main and supplementary equations of IAWPS-95
8) Evaluation
   Accuracy:
   Deviation from fundamental equation on T, v, s, C_p, $C_{v,}$ and w.

Test on several programs (This has been tested by using IF97 double precision version):
Overall accuracy
Effect of discontinuity at cell boundaries

9) Evaluation Task Group:
To aid the theoretical testing, two members for the Evaluation Task Group were added, Professor H.J. Kretzschmar and Ms. K. Knobloch.

Mr. Miyagawa will provide draft documentation and software within four months to the chair of the Evaluation Task Group, Mr. Ingo Weber.

Item #6 – A status report was given on the Development of Supplementary Backward Equations T(p,h) and T(p,s) for the Critical and Supercritical Regions of Water and Steam . These equations would be consistent with IAPWS-IF97. In Prague, an international survey had indicated that the backward equations for Temperature as a function of pressure and enthalpy, and Temperature as a function of pressure and entropy should be developed. IAPWS-IF97 region 3 is subdivided into three sub-regions, 3a, 3b, and 3c. The ratio of speed of using an iterative approach versus using the backward equations varies with sub-region; 3a=16.0, 3b=23.0, 3c=33.1. It was concluded that backward equations appear feasible in region 3 with numerical consistency of Temperature within 0.025 K. Final set of backward equations for region 3 of IAPWS-IF97 will be presented at the 2002 fall meeting. To ensure the need of industry for such equations, the chair of IC will conduct an informal survey.

The joint session of IC and TPWS working groups ended; Dr. Friend proceeded with the TPWS agenda items. After finishing TPWS agenda items, the joint session of IC and TPWS working groups was opened again. Kiyoshi Miyagawa acted as the chair.

Item #7 – A presentation on the Iterative Calculation of the Functions p(h,s) and T(h,s) using IAPWS-IF97 Basic and Backward Equations was made by Ms. K. Knobloch. In the presentation, the danger of using a single dimensional iterative procedure utilizing a mixture of Forward and Backward equations was discussed. To prevent a possible build up of deviations, it is imperative that a two dimensional approach be taken where a single set of independent parameters are chosen.

Item #8 – At the evening joint session at the hotel, the Uncertainties of IAPWS-IF97 were discussed. A power plant engineer had inquired about the uncertainty of the industrial formulation (IAPWS-IF97). It was agreed that IAPWS-95 is the internationally recognized standard for accepted steam properties. It was further decided that an Informatory Note be prepared on the "Uncertainties associated with steam properties calculated with IAPWS-IF97." Included with the Informatory Note would be a plot of uncertainties for the specific volume (v), specific heat at constant pressure (C_p), enthalpy (h), speed of sound (w), and saturation pressure versus temperature. A task group was formed to prepare the Informatory Note consisting of Professor Wolfgang Wagner (chair), Dr. Allan Harvey, and Mr. Ingo Weber. The following schedule was established:

April 30, 2002 -- Draft of Note prepared by W. Wagner sent to Task Group members and members of IC Working Group.
May 31, 2002 -- Chair of IC Working Group to send corrected document to national committees and executive committee with intent for approval at fall meeting in Argentina.

The joint session was concluded at this point.

At a separate IC meeting, the following items were addressed.

Item #9 – Topics on the implementation of IAPWS-IF97 was presented by Mr. Nobuo Okita of the Toshiba Corporation. The problems associated with deviations between the IFC-67 and IF97 in terms of enthalpies was discussed. A discussion ensued about the effect of the formulations on section efficiencies. Consensus on obtaining a single approach to this variation was not reached.

Item #10 – A new name of the IC Working Group was discussed. Four different options were initially offered by the chairman. The mission of the working group was to:

a) Collect needs from industry.
b) Provide industrial requirements to scientists.
c) Disseminate scientifically based solutions.

Based on the mission, a motion was made by Mr. Ingo Weber to rename the working group to, 'Industrial Requirements and Resolutions" (IRR). A vote was taken, with the vast majority agreeing that the new name be recommended to the Executive committee for adoption.

The final joint session of IC and TPWS occurred on Thursday, September 13th.

Item #11 – ICRN for metastable steam region
See TPWS minutes

Item #12 – Web site issues
See TPWS minutes

Item #13 – Membership of IC Working Group

a) Proposed new member – Dr. Gerald Feller of Siemens Westinghouse; consensus reached to recommend membership of Dr. Gerald Feller to Executive Committee.
b) Resignation of long standing member, Mr. Robert Spencer. It was recommended that the IC Chairman should write a special letter of thanks to Mr. Spencer for his many years of dedicated service.
c) Unknown status of Mr. Jesse Sewell – Dr. Jim Bellows or Dr. Allan Harvey will attempt to obtain an e-mail address for Mr. Sewell and provide that address to Executive Secretary Barry Dooley and chairman Miyagawa.

d) A general discussion on membership ensued. The following guidelines were recommended:
   i) No strict deadline for membership based on attendance.
   ii) National Committee should review the members from their country who are on the roster and make recommendations to the working group chairmen on whether to drop an inactive member.

Item #14 – IAPWS Structure
See TPWS minutes

Item #15 – Preparation of report to Executive Committee
Preparation of the report to the Executive Committee will be undertaken by the chair and the clerk of minutes.

Item #16 –Adjournment
The meeting was adjourned by K. Miyagawa at 15:30 on September 13th.

APPENDIX A -- AGENDA FOR INDUSTRIAL CALCULATIONS WORKING GROUP

IC Business

1) Approval of Agenda
2) appointment of Clerk of Minutes
3) Approval of minutes from Prague

Joint Session with TPWS

4) Supplementary Release on IAPWS-IF97 Backward Function **p(h,s)**
    4a) Report of the Evaluation Task Group
    4b) Acceptance of the Supplementary Release
5) Progress Report of the Evaluation Task Group for the Guideline on the Tabular Taylor Series Expansion (TTSE) Method.
6) Progress Report of the Task Group for the Development of the IAPWS-IF97 Backward Equations in Region 3

7) Topics on the Calculation of the Functions **p(h,s)** and **T(h,s)** using IAPWS-IF97 Basic and Backward Equations
8) Uncertainties in IAPWS-IF97

SEPARATE SESSION

9) Topics on the implementation of IAPWS-IF97
10) New name of the IC Working Group

JOINT SESSION WITH TPWS

11) ICRN for metastable steam region
12) Web site issues for Working Groups
13) Membership
14) New Business
    14a) IAPWS Goals and Structure Discussion with Recommendations
15) Preparation of report to Executive Committee
16) Adjournment