Attachment 10

August 29, 2004

The International Association for the Properties of Water and Steam
http://www.iapws.org

Working group 'Power Cycle Chemistry (PCC)

Chair: André Zeijseink, andre.zeijseink@kema.com
Vice-Chair: Michael Rziha, michael.rziha@siemens.com, Siemens, Erlangen, Germany
Robert Svoboda, robert.svoboda@power.alstom.com, Alstom, Baden, Switzerland

Flow-Accelerated Corrosion of Carbon Steel in PWR Secondary Cooling Water Conditions

Proposal for An International Collaboration on Flow Assisted Corrosion between Japan and Canada (2004-2005)

Proposed by

Prof. Shunsuke Uchida, Tohoku University, Japan, shunsuke.uchida@qse.tohoku.ac.jp
Prof. Peter R. Tremaine, University of Guelph, tremaine@uoguelph.ca

Supported by "Nuclear Committee" of IAPWS

Objectives:

Latest accident of ruptures of the feed water piping in Mihama-3 plant realized us importance of flow assisted corrosions (FAC) of carbon steel under reducing aqueous conditions. Latest research results on FAC showed that too low electrochemical corrosion potential (ECP) also enhanced FAC. The safety zone of ECP for avoid sereous FAC should be reevaluated based on the latest data. An "International Collaboration" in proposed for developing abilities of young researchers, Tomonori Satoh*, on understanding of FAC and setting future subjects in the fields of engineering.

Description:

1. Date survey:

   Tremendous amounts of data are avilable on FAC. The latest ones shows the effects of ECP on FAC. Too low ECP often enhanced FAC. In order to point out the threshold ECP to avoid FAC, the data should be compiled. The data on the effects of temperature, materials, geometry and flow velocity on FAC should be also compiled. [TU,UNB, VGB, Framatom-ANP]

2. Understanding the gaps between the experimental conditions and operational conditions in the plants

   ECP measurement in the operating plants is still difficult technology. Oxygen concentrations, conductivity and pH are usual data to identify corrosive conditions. To bridge the gaps between

   ECP and measured elemental data ([O_2], conductivity, pH, temperature, materials, geometory and flow velocity), suitable model based on the experimantal data are to be proposed.

   [TU, UNB, VGB, Framatom-ANP]

3. Learning sufficient skill to promote the experiments on FAC

   By joining the FAC test loop experiments in UNB, sufficient skill to promote the experiments on FAC is to be obtained. [TU, UNB]

4. Propose future subjects on FAC experiments

   It is very difficult to understand total phenomena of FAC in the operating plants. Furthur studies should be concluded. Future subjects on FAC and some bridging techniques are proposed.

   [TU,UNB, VGB, Framatom-ANP]

   The details should be discussed with Prof. D. H. Lister of UNB and others in the related institutes.

Deliverables:

Brief reports corresponding to the descriptions mentioned above will be submitted to the PCC working group and also to the Executive Committee of the IAPWS.

Time frame:

Planned start date: October 1, 2004

Milestones:

- December 30 Date survey, To select the experimental subject to be carried out at University of New Branswick
- Feburary 10 Preparation for the experiments and travelling
- March 25 Experimental works
- April 30 Compiling the report

The details should be discussed with Prof. D. H. Lister of UNB and others in the related institutes.

Anticipated impact:

The data obtained during the international collaboration can be appreciated by the Nuclear Committee.

The educated young researcher should become key persons in near future in the field of researches in interactions between materials and water at elevated temperature.

Budget requested from IAPWS for the period of October 1, 2004 through May 30, 2005

Total: 5,000$ (travelling: 2,000$, living: 3,000$)

Details; Tickets for Round Trip lNarita- New York - Montreal - Frederikton, Canada]
2,000$

Tickets for Local Round Trip [Sendai - Narita] 200$

Travelling cut to 2,000$

Hotels (50$/day x 40days)
2,000$

Local Transportation (Rent Car 1000$/month x 1.5 months)
1,500$

Living cut to 3,000$

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Budget requested from other sources:

Total: 5,000$ (experiment supplies: 5,000$)

The amounts will be supported by Tohoku University.

The details should be discussed with Prof. D. H. Lister of UNB and others in the related institutes.

Abbreviations

TU:	Tohoku University
UNB:	University of New Branswick
VGB:	VGB PowerTech e.V

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*** Tomonori Satoh**

Name: Tomonori Satoh
Student: PhD Course, Quantum Science and Energy Enineering, Graduate School of Engineering, Tohoku University
Birth date: May, 8, 1975 (29 years old)
Birthplace: Aomori, Japan
Education: BS, Quantum Science and Energy Enineering, Tohoku University (Mar, 2000)
MS, Quantum Science and Energy Enineering, Tohoku University (Mar, 2002)
PhD, Quantum Science and Energy Enineering, Tohoku University (Promised on Mar, 2005)
Awards:
2002 Okamoto Award [Financial support to attend Int. Water Chemistry Conf. of Nuclear Power Systems, Avignon, France, Apr. 2002]
2003 Okamoto Award [Financial support to attend 11th Int. Sym. Environmental Degradation of Materials of muclear power palnts, Stevenson, WA, USA, Aug. 2003]
2003 Inoue Award, Aoba Industrial Forum, Sendai "Determination of Corrosive Conditions of BWR primary cooling Systems"
2004 36th Award for Emerging Technology, Atomic Energy Society of Japan "Development of a method to determine water chemistry in a crack tip under irradiation for evaluating irradiation assisted stress corrosion cracking (IASCC)"

Major Publications:

1) T. Satoh, K. Furukawa, K. Iinuma, Y. Satoh and S. Uchida, "Water Chemistry in a Crack Tip underIrradiation, (I) –Evaluation of Gamma-ray Energy Deposition in a Crack Tip-", Journal of Nuclear Science and Technology, 38, 773-779, (2001)
2) Y. Murayama, T. Satoh, S. Uchida, S. Nagata, T. Satoh, Y. Wada and M. Tachibana , "Effect of Hydrogen Peroxide on Intergranular Stress Corrosion Cracking of Stainless Steel in High Temperature Water, (V) –Characterization of Oxide Film on Stainless Steel by Multilateral Surface Analyses", Journal of Nuclear Science and Technology, 39, 1199-1206, (2002)
3) T. Satoh, Y. Satoh and S. Uchida, "Water Chemistry in a Crack Tip under Irradiation, (II) – Evaluation of Oxidant Concentration in the Crack Tip-", Journal of Nuclear Science and Technology, 40, 334-342, (2003)
4) T. Satoh, S. Uchida, K. Furukawa, K. Iinuma and Y. Satoh, "A Model to Predict Crack Propagation Rate for Stress Corrosion Cracking of Stainless Steel under Gamma Ray Irradiation", Proceedings of 11th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, Stevenson, Washington, Aug.10-14, 2003, in CD-ROM, (2003)
5) S. Uchida, T. Satoh, K. Furukawa, Y. Murayama, J. Sugama, K. Iinuma, Y. Satoh, Y. Wada anhd M. Tachibana, "Characterization of Oxide Films on Stainless Steel Exposed to Hydrogen Peroxide and Oxygen in High Temperature Water", American Nuclear Society Proceedings of 11th International Conference on Environmental Degradation on Materials in Nuclear Power Systems; Water Reactors, Aug. 10-14, 2003, Stevenson, Washington, American Nuclear Society (2003) (CD).
6) T. Satoh, S. Uchida, J. Sugama, N. Yamashiro, T. Hirose, Y. Morishima, Y. Satoh and K. Iinuma, "Effects of Hydrogen Peroxide on Corrosion of Stainless Steel (I) - Improved Control of Hydrogen Peroxide Remaining in a High Temperature High Pressure Hydrogen Peroxide Loop", Journal of Nuclear Science and Technology, 41, 610- 618 (2004)

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8) N. Yamashiro, S. Uchida, Y. Satoh, Y. Morishima, H. Yokoyama, T. Satoh, J, Sugama and R. Yamada , "Determination of Hydrogen Peroxide in Pure Water by Chemiluminescence Detection (I) - Flow Cell Type Hydrogen Peroxide Detector", Journal of NUCLEAR SCIENCE and TECHNOLOGY, 41, 890-897 (2004)
9) S. Uchida, Y. Satoh, N. Yamashiro and T. Satoh, "Determination of Hydrogen Peroxide in Pure Water by Chemiluminescence Detection (II) - Theoretical Analysis of Luminol Chemiluminescence Processes", Journal of NUCLEAR SCIENCE and TECHNOLOGY, 41, 898-906 (2004)

Attachment 11

Final report on “Nuclear Committee” of IAPWS

September 2, 2004

Nuclear Committee Members

Dr. Clifford Davis	Idaho National Engineering & Environmental Laboratory, USA
Prof. Derek H. Lister	University of New Brunswick, Canada
Prof. Takayuki Mizuno	Mie University, Japan
Dr. A. Rudge	Brithish Energy Generation Ltd, UK
Dr. Ulrich Staudt	VGB Power Tech e.V. , Germany
Prof. Hiroshi Takaku	Shinshu University, Japan
Dr. Hideki Takiguchi	The Japan Atomic Power Company, Japan
Prof. Shunsuke Uchida,	Chair, Tohoku University , Sendai , Japan
Dr. Milan Zmitko	Nuclear Research Institute Rez plc, Czech

ABSTRACT

In order to submit research subjects related to water chemistry of nuclear power cycles to IAPWS, a committee, “Nuclear Committee” has been organized and discussed about water chemistry and materials in power plants for a year. Precise and reliable evaluations of water chemistry data are required to improve plant reliability and safety. For this, quality assurance of the water chemistry data acquisition system is needed. At the same time, theoretical models are being applied to bridge the gaps between measured water chemistry data and the information desired to understand the interaction of materials and cooling water in plants. Major models which have already been applied for plant evaluation are:

(1) water radiolysis models for BWRs and PWRs;
(2) crevice radiolysis model for SCC in BWRs; and
(3) crevice pH model for SG tubing in PWRs.

High temperature water chemistry sensors and automatic plant diagnostic systems based on water chemistry data have been applied in only restricted areas. ECP sensors are gaining popularity as tools to determine the effects of hydrogen injection in BWR systems.

1. Introduction

The IAPWS used to be supported mainly by scientists and engineers related to thermal power plants. Recently, few members came from nuclear power fields. These members have been expected to submit some new research subjects related to nuclear power plants. At the 2003 annual meeting of ICPWS in Vejle, Denmark (August 2003) a new committee “Nuclear Committee” was established to discuss chemical phenomena shown in nuclear power plants, to summarize them from the scientific viewpoints and then to submit the suitable research subjects.

Scientists would like to understand phenomena in plants, while plant operators and supervisors would like to have economical and comfortable plant operations. The gaps between both should be bridged based on phenomenological approaches. Unfortunately, only few subjects will be proposed by plant chemists. Scientists should join to plant chemists to pick up the subjects in plants. Collaboration tasks are desirable to understand effectively phenomena related to plant chemistry and material behaviors in plants. Major phenomena and subjects are listed as a result of discussion among scientists, which should be reviewed by plant chemists for submitting to the IAPWS members.

One of the benefits of nuclear power plants circuit chemistry is existence of radioactive species. As a result of radioactive analysis, behavior of low concentration species can be often measurable, their histories in the circuits, e.g., generation, transfer and final accumulation, are traceable and then fundamental phenomena are understandable. High radiation level around nuclear reactor systems often prevents easier accessibility to the plants to acquire water chemistry data thought. Comparative studies of PWR and BWR circuit chemistry are often beneficial to understand phenomena at elevated temperature, though their chemical conditions are much different each other. Comparative studies of nuclear and thermal power circuits are also useful to understand phenomena, though both temperature ranges are much different.

2. Water Chemistry Data Acquisition Systems

Cooling systems, major components and water chemistry differ in BWR and PWR plants. Procedures to measure water chemistry are also different in both reactor systems. At the same, common points in both reactor systems should also be discussed from the viewpoints of water chemistry data acquisition systems.

It is easy how to take data from the in-line monitors into the computer systems; water chemistry data from the sampled2 water used to be inputted into the computer system by plant chemists through keyboard entry. Large improvements have been reported in the latest plants on automatic analysis of chemical and radioactive nuclide data. Chemical species and radioactive nuclides collected on membrane filters are analyzed by X-ray fluorescence analyzer and gamma ray spectrometer, respectively, and then the measured data are transferred from the analyzers to the computer system directly [1]. Accumulated data are stored in a host computer (data server) allowing easy observation of plant water chemistry. The data numbers are also reduced to be compiled for daily, weekly and monthly documents (reports). Plant chemists, operators and supervisors through the computer network share the original data and also the reduced data. On-line ion chromatographs have been applied in plants for fully automatic data acquisition for the concentrations of anion and cation species, where the data are transferred to the laboratory data server through floppy disks or in the direct connection through the computer network [1]. The water chemistry data server is the center of the water chemistry data net work system, connecting with the operation and control computer systems to take plant operational data and to give water chemistry conditions to plant operators.

Trend and transient analyses are important evaluation procedures. General patterns of the data are compared with those of other plant data. Fuel integrity checking is one of the most important procedures for plant chemists and an important concern for plant operators and supervisors.

There are some gaps between the measured water chemistry data and information to understand plant conditions and interactions between materials and cooling water, which are shown in **Table 1.**

Table 1 Gaps between desired information and measured data (Beyond water chemistry data)

Desired information to understand in-plant phenomena	Measured WC data in plants	Major measures to bridge the gaps
Corrosive conditions [H_2O_2, O_2, H_2]	• Measured [O_2, H_2]	• Theoretical models for water radiolysis • HT O_2 sensors • ECP sensors
Crevice water chemistry	• Bulk water chemistry	• Theoretical crevice radiolysis models • Theoretical & empirical models for impurity concentration in crack tip
Crack propagation rate	• Crack growth rate in simulated condition	• HT crack growth rate sensors • Theoretical & empirical models for crack propagation rate
Soluble and insoluble metallic species	• Saturated concentrations along sampling lime	• Solubility analysis & deposition/release analysis along sampling lime • High temperature conductivity sensors
High temperature pH	• pH at cooled water	• Theoretical evaluation • HT pH sensors
Properties of oxide film on sampled specimens	• Characterization of oxide film	• Theoretical oxidation models • HT impedance sensors

HT: high temperature

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To evaluate plant condition by using water chemistry data, two points should be carefully considered. The first point is quality assurance of water chemistry data and the other is bridging the gaps between desired information and measured data.

3. Major subjects to be proposed to PCAS group

Newly proposed subjects from the viewpoints of nuclear plant chemistry (**Table 2**) are discussed as follows.

Table 2 Proposed major subjects for discussion

1) Water chemistry general	Quality assurance of Water Chemistry Data
2) Water chemistry control	Chemical dosage
3) Sampling and analytical technology	Suitable sampling procedures
	Automatic analytical procedures
4) Development and application of water chemistry sensors	High temperature water chemistry sensors
5) Understanding materials-water interactions*	Corrosive conditions
	ECP, radiolytic species, H_2O_2
	Water radiolysis models for BWRs and PWRs
	Crevice radiolysis model for SCC in BWRs
	Crevice pH model for SG tubing in PWRs
	Oxidation and reduction of metals
	Cupper behavior
	Solubility of metallic ions in steam
	Nucleation and condensation of impurities in steam
	Condensation and deposition of metallic
	Oxide film morphology at elevated temperature
	Flow assisted corrosion (FAC)

* Major gaps between the desired information to understand the phenomena and measured data

3.1 Water chemistry general

(1) Quality Assurance of Water Chemistry Data

Evaluation should be based on reliable data. For this, quality assurance of water chemistry data is essential. Standardization of data acquisition procedures is required to obtain qualified data, where sampling location & periods, sampling procedures and analytical instruments to determine chemical and radioactive components, calibration procedures for the instrument and their frequencies, training of plant chemists and documentation guides are clearly defined.

At the same time traceability of water chemistry data is required. For this, standard procedures for document management should be established. Quality assurance of water chemistry data in thermal power plants have been established and the details are published as one of the Japan Industrial Standards [5].

Enthusiastic promotion of quality assurance of water chemistry data in nuclear power plants based on light water reactors and establishing the standard for water chemistry data acquisition and processing are being carried on as one of the most important activities of the Research Committee on “Water Chemistry Standard” of Atomic Energy Society of Japan.

3.2 Water chemistry control

Corrosive conditions are control by chemical dosage, e.g., hydrogen injection for reducing [O_2], pH control for reducing corrosion rate, Zn injection for reducing activation deposition. For this, water radiolysis should be clearly understood in nuclear plant circuits. Theoretical models have been developed but more precise data base obtained at elevated temperature should be obtained to support the water radiolysis model and to keep sufficient accuracy.

3.3 Sampling and analytical technology

Changes in mass and chemical forms of targets species during cooling down process along the sampling line should be clearly understood. Kinetic evaluation of chemical form change and deposition and release of species on tubing wall are carefully analyzed. Each of phenomena should be discussed in oxidation and reduction of metallic species.

3.4 Development and application of water chemistry sensors

(1) High temperature water chemistry sensors

Water chemistry at elevated temperature are extrapolated by applying suitable model to evaluate interaction between water and materials in plant circuits. In order to confirm justification of the extrapolation, direct measurements of water chemistry parameters with high temperature water chemistry sensors are desirable. High temperature sensors for oxygen, hydrogen, hydrogen peroxide, pH and conductivity and in-situ measurement devices for oxide surface observation, morphology, electrochemical corrosion potential and crack propagation are requested. These sensors are applied in laboratories first and then applied in plants if they have sufficient reliability.

Some of high temperature sensors applied at operating plants [1], [5]. Most of them are sensors for structural material integrity test. High temperature reference electrodes for electrochemical corrosion potential measurements and contact tension specimens for crack propagation measurements are applied for task force of hydrogen water chemistry.

In order to obtain a reductive environment and thus mitigate secondary side corrosion of steam generator tubing, the optimum hydrazine content in the secondary system of PWR should be discussed based on ECP measurement. However, ECP would be carried out only in a very few units. Once the optimum hydrazine condition is defined, the plant staff will only routinely monitor hydrazine and ECP measurements can be terminated. In stead of direct ECP measurement, a combination approach of concentration measurement of anions and cations with ion chromatograph and empirical calculation based on crevice concentration factors and pH evaluation has been successfully applied to determine the corrosive conditions at the tubing and the crevice between the tubing and the supporting plate.

3.5 Understanding materials-water interaction

(1) Corrosive conditions

ECP (electrochemical corrosion potential) can be measured in several locations in the primary coolant at elevated temperature and extrapolated to the location of interest to evaluate corrosive conditions of the target structures. Conductivities and pH are measured at room temperature and their effects on the materials should be considered by extrapolating them to values at elevated temperature. One of the most important radiolytic species, H_2O_2, which cannot be measured in the sampled water, should be determined by the theoretical rater radiolysis model along with O_2 and H_2 at the location of interest [6].

(i) water radiolysis models for evaluating corrosive conditions in BWRs and PWRs [7], [8];
(ii) crevice radiolysis model for estimating crack growth rate of SCC in BWRs [9]; and
(iii) crevice pH model for evaluating corrosive conditions in crevices between SG tubing and tube support plate in PWRs [10].

Major gaps between the desired information to understand the phenomena and measured data are shown in Table 5 with measures to bridge these gaps.

(2) Oxidation and reduction of metals

Most fundamental phenomena of water and metal interaction at elevated temperature are oxidation and reduction of metals. The phenomena are affected by parameters determined by the results of interaction as well as by combined parameters of materials and water. Oxidation and reduction themselves are a kind of synthetic science consisting of electrochemistry, metallurgy, physics and chemistry. Corrosion, erosion, dissolution, precipitation, adsorption and deposition and fouling are related to oxidation and reduction of metals. It is wondered if scientific fields desire much breakdown of oxidation and reduction. The items are breakdown into several elemental items, which are as follows.

(i) Cupper behavior
Cupper behavior should be understood with considering oxidation and reduction on metal. Cupper ion affects oxidation of other metallic ions and at the same time be affected by co-existed ionic species and particles. Catalytic effects of cupper on oxidation and reduction of co-existed impurities are important to be determine, though it is difficult to measure them

(ii) Solubility of metallic ions in steam
Solubility of metallic ions in steam is also considered as a part of oxidation and reduction of metals in steam. It will be difficult to avoid the contribution of co-existed mists to solubility in steam.

(iii) Nucleation and condensation of impurities in steam
Condensation of impurities on heated surfaces is one of the important subjects. Their concentrations are d determined by balance of deposition and release, which might be affected by co-existed impurities. Compatibility of deposits with surfaces will be one of the key parameters to determine condensation and particle growth.

(iv) Condensation and deposition of metallic impurities in aqueous solution and steam
Compatibility of deposits with surfaces will be one of the key parameters to determine condensation and particle growth.

(v) Oxide film morphology at elevated temperature
Oxide film morphology at elevated temperature will be changed during cooling down periods. Exact examinations of the films give us important information but sometimes they are not correct. Direct measurements of oxide film properties are desired.
It is important to discussed the border between the contributions of basic research and plant application. Perfect understanding the phenomena and their application are orthodox approaches but the goals are so far. Plant chemists should be submit some speculation or their candidates, while scientists screening them based on scientific consideration.

(3) Flow induce corrosion
Erosion-corrosion is one of key issues of car4bone steel corrosion for both BWRs and PWRs.

4. Conclusions

Major subjects to be proposedFor PCAS are summarized in Table 2.

In order to improve plant reliability and safety, precise and reliable evaluations of water chemistry data have been required. For this, quality assurance of the water chemistry data acquisition system is required. The quality assurance should be supported by standard procedures for water chemistry data acquisition; these are going to be established by a committee designated by the Atomic Energy Society of Japan. Measured water chemistry data often give us only restricted information to understand materials water interaction in the plants. Theoretical models are being applied to bridge the gaps between measured water chemistry data and information desired to understand the interactions of materials and cooling water in plants. Major models already in use are:

(1) water radiolysis models for evaluating corrosive conditions in BWRs and PWRs;
(2) crevice radiolysis model for estimating crack growth rate of SCC in BWRs; and
(3) crevice pH model for evaluating corrosive conditions in crevices between SG tubing and tube support plate in PWRs.

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High temperature water chemistry sensors and automatic plant diagnostic systems have been applied in only restricted areas, but they will be applied in plants after more experience is obtained with off line Attachment 11.

diagnostic systems. ECP sensors are growing in popularity as devices to determine the effects of hydrogen injection in BWR systems.

As a result of discussion on the results of Nuclear Committee during IAPWS 2004, an international collaboration program on flow assisted corrosion has been proposed.

References

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[8] H. Takiguchi, M. Ullberg and S. Uchida, *ibid*., 41, 601 (2004)

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Abbreviations

ABWR: advanced BWR
AC: autoclave
ATR: advanced thermal reactor
BD: bottom drain line
BWR: boiling water reactor
CT: compact tension
ECP: electrochemical corrosion potential
FP: radioactive fission
IAPWS: International Association of Properties of Water and Steam
ICPWS: International Conference on Properties of Water and Steam
IGSCC: intergranular stress corrosion
JIS : Japanese Industrial Standards
KK: Kashiwazaki Kariha
LPRM: local power range monitor housing
PCAS: Physical Chemistry of Aqueous Solutions
PCC: Power cycle chemistry
PWR: pressurized water reactor
PWSCC: primary water stress corrosion cracking
SSRT: slow strain rate test

Attachment 12

REPORT

IAPWS Committee: Fuel Cell and H_2 Technologies

Mandate: update IAPWS on ongoing research, advice on problems IAPWS could work on, and on whether a task group should be formed. The committee will work for a year, and report at Kyoto, after which it is disbanded.

Recommended members: S. Lvov (chairman) and L. Shockling (Siemens Westinghouse Power Corporation).

Mr. Shockling was contacted by e-mail but never replied on the request to participate in the Committee. Dr. J. Pierre from Siemens Westinghouse, Pittsburg, PA was asked served as a consultant on the Committee.

Committee Members (2003/04): S. Lvov (chairman), J. Pierre (invited consultant from Siemens Westinghouse, Pittsburg, PA)

The main areas of R&D in Fuel Cell and H_2 Technologies those are important to IAPWS:
(1) Electrolysis of Water
(2) Electrochemical Oxidation of Fuels
(3) Electrochemical Reduction of Oxygen
(4) Properties of Proton Conducting Membranes
(5) Electrochemical and Chemical Production of Hydrogen using Hydrothermal Cycles
(6) Development of Fuel Cell–Turbine Hybrid Systems

All the areas of R&D mention above have “high priority” status in the roadmap plans of DOE, DOD, ARO, etc. and substantially funded or likely to be funded by these agencies during next 5-10 years.

The Committee activities in 2003/04 were discussed at PCAS WG meeting on Sunday, August 29th, and the WG recommendations are as follows:

(1) create an IAPWS Task Group on Fuel Cell and H_2 Technologies
(2) recommend the following task group members: S. Lvov (chairman), H. Corti, M. Nakahara, and F. Marsik.

Attachment 13

Structure of IAPWS, Awards

Following the consideration of a survey on the operation and structure of IAPWS at Vejle 2003 groups were established to consider matters of importance to IAPWS. One of these groups、Bellows, Bignold, Olavessen, Rukes and Cooper(chair) was to consider awards and was given the following mandates:

A. Advise EC on

Forms of IAPWS recognition of companies' support of IAPWS activities.

Desirability of formal written appointment by IAPWS President of WG chairs

Letter of appreciation at termination.

Desirability of new IAPWS Award for excellent leadership of WG.

B. Work with Editorial Committee on proper definition and conditions of IAPWS Awards in Bylaws, in time for vote at Kyoto meeting.

Current Awards

The details of the three current IAPWS Awards given below are useful when considering A. (4) and B. above.

[A] Gibbs Award This Award should be given to a distinguished scientist or engineer who has made a substantial contribution to the development of knowledge on the properties of water, steam and aqueous solutions at high temperatures and pressures, as well as to other areas of underlying science and technology of interest to IAPWS. The Award will not be monetary, but will consist of a plaque and or certificate and or medal that carries a considerable prestige.

The Award will be presented to the recipient on the occasion of ICPWS, and the recipient shall be invited as one of the keynote speakers at the plenary session of the Conference.

The Gibbs Award was established in 1997.

[B] Helmholtz Award This Award will be given to promising mid-career scientists and engineers (not more than one each year), who are making significant contributions to improve the existing knowledge of the properties of water, steam and aqueous solutions, or other areas within the scope of IAPWS activities interests. The candidate will normally be under the age of forty at the time of nomination.

The Helmholtz Award aims to encourage mid-career experts who may not yet be active in the IAPWS community, and to provide an opportunity for presenting their achievements at the Symposium associated with the annual IAPWS meeting.

The Award will consist of a plaque and/or certificate and is intended to be a prestigious Incentive to the career of the recipient. This Award will also provide financial support from the IAPWS for nominal travel expenses required to attend the annual meeting.

The Helmholtz Award was established in 1997.

[C] Honorary Fellowships made to IAPWS members who have made outstanding contributions to the Association, first awarded in 1981.

Comments on and recommendations for mandate A

A. (1) Forms of IAPWS recognition of companies' support of IAPWS

Companies support IAPWS in the following ways.
(i) Payment of subscriptions to the members (National Committees), who then pay the annual dues to IAPWS and also the expenses of the deputy representing the member at the annual IAPWS EC meeting.
(ii) Pay the expenses of their employees, who are members of IAPWS Working Groups, to attend the annual IAPWS meeting.
(iii) Financial support for an ICPWS, normally from companies in the country of the member hosting the particular ICPWS.

Recognition of (i) appears to lie with the National Committee and can take various forms such as
(a) declaration of sponsorship of the National Committee on its web site and elsewhere.
(b) Provide complementary copies of IAPWS publications such as the Atlas or the proceedings of the ICPWS.
(c) invitations of other company employees to any symposia or other events of interest to the company that the National Committee have organised.

(Recommend (a), (b) and (c) to National Committees)

Recognition of (ii) If the employee is a member of the National Committee then actions under (i) cover this situation. In the case of a WG member who is employed by an organisation that does not sponsor a National Committee then it may be the case that letters of invitation to IAPWS WG meetings, letters of welcome to WG membership and letters of thanks for involvement in IAPWS tasks, may be of value. (the use of web registration IAPWS meetings looses one of these).

(Recommend to EC)

Recognition of (iii) is made in appropriate acknowledgement in ICPWS documents including the proceedings.

(Recommend to ICPWS Organising Committee)

The use of plaques for (i) or (ii) seems to have difficulties in ascertaining that all companies who have supported IAPWS though National Committees treated equally.

A. (2) Desirability of formal written appointment by IAPWS President of WG chairs.
It is important to establish the formal letter of appointment.

(Recommend to EC)

A. (3) Letter of appreciation at termination.
It is highly desirable that the retiring WG chair should receive a letter of appreciation.

(Recommend to EC)

A. (4) Desirability of new IAPWS Award for excellent leadership of WG.
Any retiring WG chair, who has made a significant contribution to the business of IAPWS will be a strong candidate for Honorary Fellowship. It should not be necessary to create another award.

Attachment 14

REPORT

IAPWS Task Group: Electrochemical Processes in High-Temperature Aqueous Systems

Mandate: The task group should be formulated and start their work as soon as possible. It should be operational, and report by the time of the Kyoto meeting. The chair should have the discretion to select further members and co-opted experts.

Members: S. Lvov (chairman), D. Macdonald, E. Maughan, M. Nakahara, T. Petrova, and S. Uchida

The Task Group has extensively communicated in 2003/04 by e-mail and formulated the following areas of R&D that are important to IAPWS:

(1) Potentiometry
(2) pH Measurements
(3) Electrochemical Monitoring of Solution Chemistry
(4) Electrochemical Kinetics Measurements
(5) Corrosion Metals and Alloys
(6) Electrokinetic Measurements
(7) Electrochemical Production of Substances (for example, hydrogen production)
(8) Electrochemical Production of Electrical Energy (for example, fuel cells)
(9) Electrochemical Conductance Measurements.

The Task Group activities in 2003/04 were discussed at PCAS WG meeting on Sunday, August 29th, and the WG recommendations are as follows:

(1) continue the Task Group activities in 2004/2005,
(2) add D. Palmer to the members list
(3) communicate to PCC to formulate details of the listed above areas of research

Attachment 15

EDUCATION AND OUTREACH TASK GROUP

According to the Minutes of the Vejle meeting (pp. 19-20) the tasks of this TG are:
• Define educational and outreach projects.
• Work with national committees active in this area.
• Attract volunteers.
• Explore possibilities of obtaining funding.

• Proposed projects.
After discussions with members of different National Committees the proposed activities in the near future should aim to three targets: young researchers, university students and high school students. They are the following (in decreasing order of priority)

1- Promote the participation of PhD students and young researchers in Annual IAPWS meetings
This activity could start at the next IAPWS meeting at Greece, with the participation of local and foreign students. The best option seems to be organize one or two special sessions in the framework of WG joint meetings.
Funds for encouraging the participation of students in IAPWS activities would come from IAPWS (directly or through funds required for international collaborations). Local agencies could eventually contribute.

2- Develop an educational web page and expand the FAQ section of the IAPWS web site.
FAQ items could be added, such as those related to new technology (fuel cells for instance), environmental issues, etc.
Additionally, an independent web page could be created, linked to the IAPWS site, which aims to a different people target: university students and high school students and teachers. The content of this web page has to be defined in connection with point (3) during the next year.

3- Educational Booklet.
It aims to develope educational material for university and high school students related with the use of water and steam in the power industry. Its content will be defined during the next year and it will be complementary with other electronic educational tools (CD, web page). It is a long term project (2-3 years).

Task Group Members

Confirmed members of this Task Group are: H.Corti (ABBC, chair), M.Assael (Greece), R.Harris (BIAPWS), L.Trevani (Canada), L.Olavessen (USA), A.Harvey (USA, consultant).
One of the task for the next year is try to attract volunteers of other National Committees representing different WGs.

Attachment 15

Funding

The first activity will require IAPWS support.

The preparation of electronic and printed material will require funds from local or international agencies.

Attachment 16

New Task Group – Environmental issues

Rev.1 Sep.1st, 2004
August 29th, 2004
Nobuo Okita

1. Main task and object for the new task group
   Investigate current status and future directions, and research the subjects to which IAPWS can contribute as for environmental issues.
2. Task member
   First-level subcommittee members: Okita, Parry, Weber, Zeijseink
   Additional, full committee: Nakahara, Assael, Olavessen, Span, Regazzoni(Argentina)
3. Key technologies to be considered
   Three stages QFD (quality function deployment) is carried out as below in order to collect and select the key technologies for solutions to environmental issues.

QFD-1: Concept of solutions

Solutions / Issues	High efficiency	Recycle	Treatment	Zero emission	Maintain efficiency
CO2 emissions	++		+	+++	+
Mercury (heavy metal) emissions	+	+	++	+++	+
NOx & SOx emissions	+	+	++	+++	+
Effluent		++	+++	+	
Waste		+++	++	+	
Sea or river water temperature rise	+++				++

Notes) +: weak correlation ++: moderate correlation +++: strong correlation

QFD-2: Technology fields for solutions

Fields / Solutions	High temp. Low NOx CC	USC plant	Nuclear energy	Renewable energy	Other new cycles & systems	Energy Storage
High efficiency	+++	++	+		+++	+
Recycle	+	+	++	+++	++	++
Water treatment	++	++	+++	+	+	
Flue gas treatment	+++	+++	++	+	+	
Fuel treatment			++	++	+++	++
Zero emission	+		++	++	+++	
Maintain efficiency	++	+	+	+	+	+++

Attachment 16

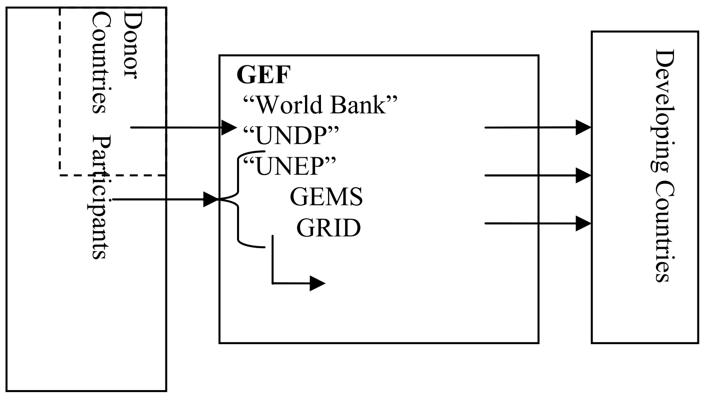
QFD-3: Key Technologies for solutions relating to water and steam (to be discussed)

Fields & Solutions	Technologies	Steam cooling	Steam-Water injection	SCWO	SCR SNCR	OT	Chemical reactions	Anti-erosion corrosion
Fields	High temp. & Low NOx CC	+++	++	++	++	++		
	USC plant	++		++	+++	++		+++
	Nuclear energy			+++		+++	+	++
	Geothermal system		++	++			+	+++
	Fuel cell			+			+++	
	Biomass energy			++	++	++	++	++
	PFBC, A-PFBC		++		+++	+	++	++
	IGCC,IGFC	+	++	+	++	+	+++	++
	HAT (SAT) cycle		+++		+	+	++	+
	New H2 system	++	++			+	+++	++
	Energy Storage						+++	
Solutions	High efficiency	+++	++				+	+
	Recycle			++			+	
	Water treatment			+++		+++	++	
	Flue gas treatment			+++	+++		++	
	Fuel treatment		+++	++	++		+	
	Zero emission			++			+++	
	Maintain efficiency	++	++			++		+++

1. Experts and related committees (to be discussed)
   Japan: Dr. Nakahara & Dr. Matsubayashi, Kyoto University (SCWO)
      Dr. Hamamatsu & Ikemoto, CRIEPI (Environment Issues)
      Dr. Takaku, Shinshu University (Water treatment)
      Dr. Yamazaki & Dr. Uchida, Tohoku University (Chemical reactions& Nuclear energy)
      National Institute of Advanced Industrial Science and Technologies (General issues)
         Supercritical Fluid Research Center (SCWO)
      National Institute for Environmental Studies (Environment Issues)
      Toyohashi University of Technology (SCWO)
   Germany: International Journal for Electricity and Heat Generation (General issues)
         Department of Business and Labor of the German government (General Issues)
   USA: U.S. Environmental Protection Agency (Environment Issues, SCR) :www.epa.gov
      Energy and Environmental Research Center (Environment Issues, SCR)
      www.undeerc.org
      Institute of Clean Air Companies (SCR, SNCR) : www.icac.com
      EPRI (General Issues) : www.epri.com

Attachment 16

Reference: International Organizations for environmental issues



GEF: Global Environmental Facility
UNDP:United Nations Development Programme
UNEP: United Nations Environment Programme
GEMS: Global Environment Monitoring System
GRID: Global Resource Information Database

5. Current status and future direction in Japan ***and USA***
   (1) High Temperature & Low NOx Combined Cycle
   1450degC Gas turbine combined cycle using steam cooling for combustion is operating in Tohoku Electric Power Co.
   1500degC Gas turbine combined cycle using steam cooling for 1st &2nd blades is under construction in Tokyo Electric Power Co. More than 58%(LHV) of plant efficiency can be realized.
   Steam purification for the cooling is strictly controlled in order to maintain reliability.
   NOx is guaranteed below 5ppm at the stuck by using dry low NOx combustor and SCR with ammonia.
   Future direction will be more than 59% of plant efficiency and below 3ppm of NOx emission.
   In USA, in order to avoid "yellow plume" form exhaust gas at low load, quick start of gas turbine is important.
   (2) USC plant
   The highest temperature is 600/610deg C and the highest pressure is 31MPa in operating plants.
   Technologies for the 630/630deg C has been developed and completed, however, Japanese domestic demand for electricity is not so high now. Then it will take more time in Japan to realize USC plant with such high temperature.
   Future direction will be more than 700deg C USC plant which is considered to be a national R & D project in future.

   In USA, the highest applied steam condition is 1050 F with subcritical pressure, because utilities prioritize reliability.

(3) Nuclear energy
ABWR is operated applying OT in Tokyo Electric Power Co. APWR is under construction.
Plu-Thermal plan for recycle of used fuel is under consideration. Economical comparison has been discussed recently.
Future direction will be discussed further, however, it is necessary as base load in Japan.

In USA, new nuclear plants are constructed only for upgrade to exist plants, because new site can not be permitted for construction.

(4) Geothermal system
Geothermal plants are operated in Tohoku Electric Power Co. and Kyushu Electric Power Co. Binary plant is also operated as a test plant.
Water injection system is applied for cleaning steam and preventing from scale adherence to the 1^{st} nozzles and blades. ***One of the most important issue is anti-corrosion technology.***
New technology for preventing from scale adherence to the return well is also investigated.
Future direction will be to investigate how to recover or maintain the energy of steam from the well.

(5) Fuel cell
Several kinds of fuel cell are developed and operated as follows,
"Molten Carbonate Fuel Cell (MCFC)"
"Solid Oxide Fuel Cell (SOFC)"
"Phosphoric Acid Fuel Cell (PAFC)"
"Proton Exchange Membrane Fuel Cell (PEFC)"
High temperature fuel cell (MCFC & SOFC) will have great potential for future use as an alternative source of generating electricity.

(6) Biomass energy
Recently in Japan, biomass energy is focused and introduced as an economical energy by industrial users. Utilities are investigating it. Biomass fuel can be cheaply obtained rather than the conventional oil fuel.
Future direction will be to maintain reliability by boiler tube selection and flue gas treatment.

(7) PFBC and A-PFBC
Three units of PFBC with 850deg C class gas turbine are operated in commercial use and one unit is under construction.
A-PFBC with 1350deg C class gas turbine is investigated for future application

(8) IGCC and IGFC
An IGCC plant is operated as a test plant at Nakoso power station.
Future application will be IGFC system with fuel cell for higher efficiency.

(9) HAT cycle
HAT cycle or SAT cycle is under investigation as low NOx and high efficiency cycle.
SAT (Steam and Air Turbine) cycle with chemical reaction for the flue gas will reach higher efficiency.

(10) New H2 system
Hydrogen turbine system had been developed in the national R&D programme. However, it has been stopped because of the difficulty in obtaining and treating economically the hydrogen fuel. Material development or selection is half done.
Chemically recuperated gas turbine system is under investigation.
Future issue to be resolved will be economical treating system for hydrogen fuel with other use such as fuel cell.

(6) Current status and future direction in other countries

(1) Germany

Coal Fired Steam Power Plants:

Current efficiency level 47% (anthracite) and 43% (lignite). Through progress in thermodynamic and flow design, materials and coal drying techniques increase of efficiency estimated to about 51% until 2010. Fields of interests are:

- Material development for highest process parameters (700/720 C, 375 bar)
- Highly efficient steam turbines (700 to 800 C, 350 to 400 bar)
- Low NOX through optimized combustion
- Optimization of coal drying process for lignite
- Improved modeling of combustion and fouling
- Improved numerical design tools

Combined Cycle Power Plants (CCPP):

Current efficiency level 58%. Through progress in thermodynamic and flow design and materials increase of efficiency estimated to about 65% until 2010. Fields of interests are:

- Optimized design for turbine components
- Reduction of cooling air consumption in gas turbines
- Improved combustors
- Improved design and modeling tools

Integrated Gasification Combined Cycle (IGCC):

Currently several demonstration plants in Europe existing. Further demonstration project intended for 2010 – 2015. Main focus is profitability improvement and incorporation of progress in CCPP design.

Future concepts of interest (not before 2020):

CCPP with pressurized pulverized coal combustion

CCPP with pressurized fluidized bed combustion and partial gasification

Externally fired Combined Cycle (EFCC)

Hybrid power plants (CCPP with fuel cells, IGCC with fuel cells)

Humid Air Turbine cycle (HAT)

Fuel Cells:

Pressurized high temperature fuel cells (solid oxide (SOFC), molten carbonate (MCFC))

(Source: COORETEC report on R&D concepts on low emission fossil fired power plants,
Issued by the Department of Business and Labor of the German government, 12/2003)

(2) Argentina

There is interest in the academic sector and also in the government to promote the use of hydrogen, particularly that obtained from eolic and solar renewable sources to generate energy in fuel cells.

(7) The subject to which IAPWS can contribute

The previous QFDs suggest that the selected key technologies are the candidates of the subject to which IAPWS can contribute.

Each technology will be able to be discussed in the following WG's.

"Steam cooling" : TPWS, IRS, ***PCAC and PCC***

"Steam injection" : TPWS, IRS, ***PCAS and PCC***

"SCWO" : PCAS and PCC
"SCR, SNCR" : PCAS
"OT" : PCC
"Chemical Reactions" : PCAS and IRS
"Anti-erosion & corrosion" : PCC and IRS

8. Task object, directions in future and functions for the selected subjects
   To be discussed in Kyoto referring the held symposium .
   Firstly collect each country's current status and future directions as described in item #5, then draft the summary of the results and discuss further.

9. Schedule
   During Kyoto meeting: Extending the survey I did for Japan to the other member countries should be an urgent task for the respective national committees. Most importantly, review the item 7 in which I have outlined areas IAPWS could contribute to.

Attachment 17

Task group

Metastability, Nucleation, Early condensate, Droplet Sprays and Cavitation

Main subjects:

The group will provide a forum for leading researchers and practitioners to engage in debate on contemporary issues governing the state-of-the-art in nonequilibrium and metastable of water and aqueous systems. In particular:

- Phase transitions and phase diagrams of aqueous systems
  Saturation line, bubble points and dew points
- Metastable water and metastable aqueous systems
  Nucleation, cavitation, boiling and condensation
- Bubble and droplet formation and two-phase flow
- Measuring techniques for transient quantities.

More details about the task group problems see the lectures in the Symposium 4 *Nonequilibrium,Metastable and Critical States*

Attachment 17

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