

**Power Cycle Chemistry Working Group (PCC WG)
Turin, Italy, September 3rd – 8th 2023**

Revision 1.0

Monday 4th September: 10:30 – 12:00 Session

1. Introduction to PCC 2023 WG meeting

IAPWS 2023 PCC WG members were welcomed by David Addison who reviewed the schedule / agenda for the week

2. Adoption of Agenda and Minutes Approval

- The agenda was adopted and attached as PCC Attachment A.
- Minutes from PCC 2022 were approved with no changes.

3. Appointment of PCC WG Clerk of Minutes

Willy Cook (Canada) was appointed as clerk.

4. Approval of Minutes

No comments, omissions or changes suggested. Minutes approved.

5. Review of Actions from last PCC WG Meeting

From PCC-2022, 17 actions reviewed. Outstanding actions captured for follow up.

6. Willy Cook made brief presentation in memoriam for Professor Derek Lister

7. Mads Skovbjerg – Update on Int'l Collaboration Project on corrosion product transport during transient load conditions

- Filtered samples preferred for plant application – provide low-level Fe monitoring
- Correlation established between turbidity measurement and [Fe]/[Cu]
- Colour map needs to be updated to better represent plant data;
- need to include plant specific metrics such as feedwater flow rate and/or surface area to normalize the data
- Discussion followed presentation

8. IAPWS TGD Updates

Corrosion Product Transport

- Change white paper into TGD with following items further addressed

- New TGD or addition to current TGD?
- Are colour boundaries okay?
- Starting point of decay? Startup, first fire, load change?
- How to improve decay profile – operator / chemistry actions and procedures?
- Keep decay curves for both Fe and Cu?
- STG for white paper (Dooley, Thomsen, Nielsen, Vepsalainen – plus Addison, McCann)
 - New STG members for TGD development in addition to original STG
 - Skovbjerg, McAllister, Leidich

FFS in Nuclear Plants (deferred to Monday PM)

Flue Gas Condensation (covered in PCC / PCAS joint session, Monday PM)

Geothermal Plants (deferred to Monday PM)

Monday 4th September: 1:00 – 15:15

Joint PCAS and PCC WG Meeting

a) Nobuo Okita (Toshiba): Dew Point of Low Sulphur Exhaust Gas

- Update on work presented in NZ last meeting.
- New practical H₂S limits identified for inclusion in white paper
- Framework for potential TGD presented

Questions on SO₂ to SO₃ conversion in model

Task Group for White Paper / TGD development: Okita, McCann, Addison

ACTION: Addison to discuss with Andy (GE) for addition to TG

b) Ken Yoshida (Tokushima University): Reaction pathways and mechanisms of alkylamines in supercritical water as studied by NMR spectroscopy.

- Interested in FFA thermal degradation pathways investigated.
- Use of model amines (ETA, OctA) with isotope tracers to simulate FFA's
- Reaction products include the alcohol, ethene (for ETA) and isomers of octene (for OctA) that reach near equilibrium concentrations based upon modelling comparisons – different behaviour exhibited for the protonated vs neutral amine

ACTION: Suggestion to draft ICRN project on FFS decomposition products.

c) Hal Stansfield (Waltron): FAA fouling of analytical instruments and mitigations

- Loss of instrument response and accuracy due to fouling with FFS
- Tests on Na-electrode showed degraded response after a week of operation but still passes calibration – Common cleaning / regeneration not fully successful
- No apparent issues with O₂ analyzers

Suggestion to use non-ionic surfactant to remove FFS.

What products were used for the testing? FFA's mainly (commercial OLA mixture used), no FFP's tested to date.

What other instruments have been investigated? ... working toward other technologies ...

Work needs to continue be published ASAP.

Suggestion to draft ICRN project to begin immediately.

d) David Addison (PCC WG): Outline of FFS unknowns draft ICRN

- Key areas of interest (14) presented

e) Folmer Fogh (Ørsted Bioenergy & Thermal Power): Water Treatment of Flue Gas Condensate White Paper | TGD

- Development of white paper outlined and described
- Initial draft completed in March 2022 and circulated for comments.
- No work done since ...

Next steps:

- some feedback has already been collected
- Original STG to revise white paper and circulate to PCC
- Publish in PPChem

Flue Gas Condensation TDG Discussion (Barry Dooley)

- Change white paper into TGD with following items further addressed
 - Reformat for TGD
 - Add roadmaps and optimizations
 - Include customization
 - Needs international experience and review
 - Unify nomenclature
- STG members for TGD
 - Same members as white paper, plus

- Additional members: Ludwin Daal (Netherlands)

Monday 4th September: 15:45 – 16:30

IAPWS TGD Updates, Barry Dooley (con'd from AM session)

FFS in Nuclear Plants (deferred to Monday PM)

STG: Fandrich (Chair), Dooley, Cook, Stuart, Duncanson

New STG members: Bobby Svoboda

White paper development for lay-up applications with draft ready by end of 2023.

Geothermal Plants

STG: Addison (chair), Richardson, Nobu

Draft circulated for review, some comments from Japanese committee – revisions needed

Electrode Boiler Chemistry

STG: Addison (chair), Dooley, Nielsen

New STG members: Vepsäläinen, Rziha

Recent applications in USA and Ireland

White paper in development and requires international input

- Distinction between volatile and NaOH or TSP
- Needed instrumentation?
- Relation between conductivity and corrosion
- FFS use?
- Makeup requirements

STG to meet during IAPWS week to begin activities.

Amending TGDs

Refreshment of published TGDs:

- Volatile and boiler alkali treatments (Int'l Collaboration Project NZ / Canada)
 - Discuss after review of Cook presentation
- Addition of Al in volatile TGD
- Carryover as function of load changes (small addition, develop section 8 / customization)
 - Dooley, Rziha, Svoboda to revise

- Instrumentation TGD
 - o add some proxy measurements
 - o tables at back need clarifying / cleaning up
 - o TGD covers fossil / biomass – should include electrode boilers? Likely better to include in the plant-
 - o Dooley, Stansfield, Nogales, Buchner, Addison, McCann
 - o Group to meet early in IAPWS week
- Film forming substances TGDs
 - o Update with new information from IAPWS FFS conferences
- Steam purity TGD
 - o Incorporate customization per new VGB guidance
 - o Leidich, Dooley, Svoboda

Monday 4th September: 16:30 – 17:30

PCC Discussions Around a Future Industrial Steam / Heat TGD

Potential to align IAPWS guidance with industrial boiler systems

Gaps:

- Low pressure boilers / hot-water systems
- Non-demin make-up plants
 - o Common lingo means IX demin plant – need to be very clear and specific on what is meant by demin
 - o Conductivity < 0.1, silica < 30 ppb
- Condensate return
- Low heat flux biomass
- Electrode boilers
- Reboilers
- Instrumentation requirements

Does PCC want to cover some of these areas?

- Guiding principles for industrial steam plants:
 - o All ferrous
 - o No reducing agents
 - o Don't add alkalizing agents known to fail boiler tubes
 - o Measure corrosion products
 - o Instrumentation
 - o Don't add boiler chemicals in condensate or feedwater

Discussion ensued about need and value of new TGDs vs updates.

Action: flag to discuss again at IAPWS 2025 in Finland. D. Addison to provide preliminary information for PCC to review prior to IAPWS 2025.

Additional PCC Presentations

a) Monika Nielsen – SIAPWS Electrode Boiler Update

- Demonstrated phosphate hide-out and conversion to iron-phosphate
- H₂ identified in boiler water with potential of H₂ explosion

b) David Addison – NZAPWS Electrode Boiler Update

- Standardize on SWAS for NZ electrode boilers
- H₂ monitored in steam – and seen regularly – accumulation risk identified and high points vented

c) David Addison – ODA Emergency Application in a 8 MW Electrode Boiler

- ODA dosed to mitigate corrosion issues from poorly functioning deaerator

Tuesday 5th September: 09:00 – 10:30

Future of PCC Workshop – Led by Paul McCann – PCC Vice Chair

- a) Paul McCann (Vice Chair) introduced session and provided background on need for PCC rejuvenation.
- b) Questions for breakout groups (NA, SIAPWS, Central Europe, Pacific Rim, German-Suisse):
- What does PCC WG do well at the moment?
 - What does PCC WG not do well at the moment? Have you any suggestions how this could be addressed?
 - What do you want PCC to do in the future?
 - What areas should PCC focus on and/or develop?
 - Plant types, e.g. fossil, nuclear, geothermal, industrial, other;
 - Activities, e.g. TGD development, training, webinars;
 - Suggestions for TGDs – new documents, missing info, need for revision.

	1 – Canada/USA	2 - SIAPWS	3 – Central Europe	4 – NZAPWS/AUSAPWS/JAIPWS	5 – Germany etc
1. Well	<ul style="list-style-type: none"> - Collaborative working. Technical excellence - TGD output and quality, input from ICRNs and other WG's 	<ul style="list-style-type: none"> - Same as Canada/USA + - Open discussions - Very informal - Great support 	<ul style="list-style-type: none"> - Knowhow is free, easily available, international recognised group - Good way to keep up to date with what is new etc 	<ul style="list-style-type: none"> - Right people in PCC - TGDs – focused documents, need to publish recognised as priority 	<ul style="list-style-type: none"> - Same as others! - Global collaboration - Cross over of users/designers/R&D etc - Open and non competitive discussions
2. Not well	<ul style="list-style-type: none"> - Communicating what IAPWS is and what IAPWS does - Training, mentoring, bringing in the next generation for PCC - Mainly focused on ultra pure water 	<ul style="list-style-type: none"> - Timelines very long for TGDs etc - Hard to get things done between annual meetings - Unclear of how PCC functions/planning etc - Integration of new people 	<ul style="list-style-type: none"> - Communication about what PCC is and what its done - Difficult to know how to join and take part in PCC and what is going on 	<ul style="list-style-type: none"> - No clear metric for the success of the TGDs, numbers downloaded, access, who, where? - Communication within PCC is irregular - Relevance of PCC to the North American market - Value of IAPWS/PCC to new people in industry not clear 	<ul style="list-style-type: none"> - Visibility of IAPWS/PCC limited - How to get more and new members and what is the benefit of IAPWS/PCC for the companies etc
3. Future	<ul style="list-style-type: none"> - Webinars, LinkedIn, website, knowledge transfer, mentorship 	<ul style="list-style-type: none"> - webinars, how to advertise/awareness ? - Start small with webinars – intro to PCC - Podcasts 	<ul style="list-style-type: none"> - Webinars, LinkedIn, more industry/vendor people, more diversity of members - Focus on sharing knowledge - Maybe consider a name change away from "Power Cycle Chemistry" - Need to retain knowledge 	<ul style="list-style-type: none"> - Better coms, more regular coms, quarterly action update calls - Better technology for collaborative working - IAPWS associated research organisations / labs / experts - Is Water/Steam Cycle better name for PCC? 	<ul style="list-style-type: none"> - Relook/redesign IAPWS/PCC website - Make very clear the benefits of IAPWS/PCC - Increase efforts of public relations – LinkedIn etc - Make members of PCC more visible - Translate TGDs into – Spanish/Chinese etc?
4i. Plant	<ul style="list-style-type: none"> - Look outside into more industrial applications - SMRs, CCS, water reuse, hydrogen 	<ul style="list-style-type: none"> - Move beyond just fossil - SMR, CCS, eBlrs, industrial 	<ul style="list-style-type: none"> - SMR, cooling systems 	<ul style="list-style-type: none"> - Keep primary focus on what is in commercial use + track emerging industries and issues 	<ul style="list-style-type: none"> - Steam/Water cycle still needed - Supercritical water/steam systems
4ii. Activities	<ul style="list-style-type: none"> - Webinars, LinkedIn, website, knowledge transfer, mentorship 	<ul style="list-style-type: none"> - Advertising for PCC/raise awareness - Sharing of national group experiences/processes 	<ul style="list-style-type: none"> - Need to retain knowledge 	<ul style="list-style-type: none"> - More public outreach, webinars, IAPWS 101/TGDs, making them then available on YouTube etc 	<ul style="list-style-type: none"> - Training/Webinars (issues with costs/commercials etc) - Take care of existing TGDs/revisions
4iii. TGDs			<ul style="list-style-type: none"> - Boiler chemical cleaning 	<ul style="list-style-type: none"> - TGD "Management of Water/Steam Chemistry" – road map to use TGDs 	<ul style="list-style-type: none"> - Supercritical water/steam systems - Plant preservation/issues

Tuesday 5th September: 11:00 – 12:00

Hydrogen Production and Water Related Issues – Led by Kirk Buecher (PCC Vice Chair)

- a) **David Addison – Potential Water Chemistry issues in the large scale hydrogen production space introduction**
- b) **Kirk Buecher – Hydrogen Generation/Industry Space and Potential Cross Over with IAPWS PCC and other Working Groups**
 - Overview of H₂ generation technology
 - Emphasis on water quality for PEM electrolyzers (ASTM Type I, II etc)

What can PCC contribute? TGD on PEM water quality?

Include topical area for ICPWS 2024? Invite presentations in the electrochem / corrosion stream.

Discuss with electrolyzer industry, develop relationship and identify potential issues + ICRN

ACTION: Addison, Cook, Dooley, Nielsen – coordinate for electrolyzer water session at ICPWS 2024

Tuesday 5th September: 1:00 – 15:15

PCC Task Group Meeting/Working Time

Tuesday 5th September: 1:00 – 15:45

TGD-Related PCC Presentations/Updates

- a) **Taro Ichihara – Hydrogen damage in a power boiler: Correlations between damage distribution and thermal-hydraulic properties**
- b) **Ludwin Daal – BlueXPRT Netherlands Experience with Corrosion Product Sampling and Analysis**
- c) **Basil Perdicakis – Canadian Oil Sands Water/Steam Chemistry Related Changes and Improvements Since IAPWS 2019 in Banff, Canada**
- d) **Mar Nogales – Possible Updates for the IAPWS Instrumentation TGD**
- e) **Willy Cook – Boiler Electrochemical Corrosion Studies Test Rig Results Update: IAPWS Canada/NZ International Collaboration Project**

Thursday 7th September: 09:00 – 09:30

PCC Discussions Around ICPWS 2024 – led by David Addison

General Information:

- June 23-28, 2024
- Call for papers close 19th November
- PCC areas
 - Power Cycle Chemistry
 - Electrochem & Corrosion
- Time for regular PCC business – Sunday prior to conference
 - EC meeting for 1.5 hrs +
 - PCC meeting (all PCC business)
- Remainder of week for ICPWS, IAPWS General Meeting
- EC meeting on the Friday

Key focus areas:

- Chemistry, FSS, water-steam analysis

Thursday 7th September

Dedicated PCC Task Group Meeting/Working Time

Not needed, groups have meet and plans highlighted below.

Thursday 7th September: 09:30 – 10:30

IAPWS TGD's Updates (led by Barry Dooley) – progress updates from IAPWS 2023 activities and plans from Task Group Chairs

Steam purity:

- has met and methodology determine
- Frank Udo to submit to Bobby & Barry
- Perhaps new TGD emerges for updated data analysis

FFS in Nuclear:

- Fandrich to complete draft by year end

FFS in fossil:

- ICRN has been discussed and new items to be added

Corrosion products:

- still uncertainty if enough information has been collected to solidify a TGD
- Agreed to review Mads thesis, white paper 2019 and Barry's presentation
 - o e.g. what is the starting point for the decay curve, may include all
 - o what are the operating features and/or shutdown conditions that give "green" area
- All will agree path forward in next month, virtual meeting to be scheduled
- Determine who will write necessary new text
- Maintain it as a unique document
- Paul to collate comments and set

ACTION: STG to comment on path forward and set meeting by end of October 2023

Geothermal Steam:

- Addison & Nobou have meet
- Plan for "consequence table" inserted into White Paper
- Target ICPWS 2024 for approval of TGD

Flue Gas Condensation:

- Convert current white paper to TGD format
- Target ICPWS 2024 for approval of TGD

Electrode Boilers:

- Addison & Nielsen have met
- Short, concise TGD to be drafted
- Circulate pre-TGD to operators / vendors over the next year for input
- Target IAPWS 2025 for approval of TGD

Instrumentation:

- STG has met and it's already an excellent document
- Targeting minor updates
- Review by end of October and provide suggestions to STG
- Include monitoring of condensate return from process steam systems?

ACTION: STG review and send comments / additions by end of October 2023

White Papers:

- Potentially included white paper activity descriptions on new IAPWS PCC website
- Contact WG Chair for information on white papers
- Some concern about this process depending upon the area of application
- Should have PCC WG approval prior to release
- Need to develop a white paper policy

ACTION: Addison & Dooley to discuss and draft a policy for development and release of PCC white papers prior to ICPWS 2024.

International Collaboration Reports:

- Several reports are being completed. All currently “live” on the computer of the IAPWS Exec. Secretary
- Where do these “live” and who has access (OPAL terminal)
- Process to be similar to release of white papers

ACTION: Addison & Dooley to discuss and draft a policy for development and release of PCC International Collaborations prior to ICPWS 2024.

Barry Dooley comments on Future of PCC Workshop

What IAPWS PCC could do:

- Evaluation of water wall deposition loadings – do the boilers need to be chemically cleaned.
 - o Developed in ‘80s Based upon loading / thickness and incorrectly applied
 - o HRSG TGD has been developed
 - o Gap with supercritical units
 - New understanding based upon voidage of the native oxide
 - Introduce TGD?
 - o Chemical Cleaning for fossil plants
 - What could be done simply?
- IAPWS is the leading org in the world for ...
 - o FFS – based upon the international conference series
 - o HRSGs – again, based upon the international conference series
 - o Perhaps more conference series are needed
 - Corrosion products?
 - PTZ / steam turbines
- Internal organization of IAPWS
 - o 1990 Argentina – framework of IAPWS work activities developed, working groups developed
 - o Structure needs to be re-examined and how collaborative works are initiated
 - Interface between PCC and PCAS needs mending

ACTION: PCC WG Chair to discuss with PCAS Chair

Thursday 7th September: 11:00 – 12:30

PCC WG Business

Added presentation:

Frank Udo Leidich – Oxidation and corrosion behavior of steel alloys in supercritical water

a) Progress Reports 2022/2023 and Future PCC Activities

- Review of outstanding actions and new actions from 2023
- ICRN 32 – needs to go to editorial committee

b) Future direction of PCC discussions summary – proposals for future management of PCC

- Update website to add PCC information
- PCC LinkedIn page to be launched and monitored
 - o Comments that this should be done professionally and properly
 - o Dooley not overly excited about LinkedIn
- Host four webinars before ICPWS 2024
 - o Dooley to start with TGD Overview
 - o Rziha + two more
- Move to bi-monthly PCC virtual meetings via MS Teams or Zoom

PCC Chairman asked for PCC agreement on this approach. There was no objection from the PCC group in attendance.

c) Proposals for new TGD's summary

No additional discussion.

d) International Collaboration Projects

No ICPs currently ongoing, a few could be established within are of FFS and jointly between PCC and PCAS.

Process for reporting and access to ICP reports to be drafted (Action 23-10)

e) ICRNs – Review and Possible New Additions

ICRN 32 approved in 2022 needs to move to EC and Editorial Committee

FFS ICRN

Electrode Boiler ICRN – hydrogen generation

These can be drafted and passed out to national committees for review, comment and approval via postal ballot.

f) PCC Public Relations / Contribution to Press Release

g) Changes in PCC Membership and Election of Officers

New membership to PCC:

Nikko Vepsäläinen, Finland

David De Vos, Belgium

Antony Senecat, Belgium

Ronny Wagner, Germany

Antonios Thanos, Greece

New PCC Vice-Chair:

Taro Ichihara, Japan

h) Adjournment

IAPWS President made address to PCC and provided comments on planning for ICPWS 2024 and encouraged everyone to attend.

Meeting adjourned 12:15 PM September 7th, 2023.

ACTION LIST

#	PCC Area	Action	Owner	Due Date	Status
Summary of Actions carried forward					
22-3	ICRN 32	Circulate ICRN to national committees during the week so decision can be made by EC at end of week	Addison	Before Dec. 2 nd 2022	In progress
22-4	Future PCC directions	Organize two webinars	Addison	Webinar 1: Q1 of 2023 and Webinar 2: Q3 of 2023	On hold till 2023/2024 – discussion later in PCC program
22-5	Future PCC directions	Assess scope and cross-over of hydrogen generation space with PCC	Beucher	Turin 2023	Discussion later in PCC program

		and other WGs' mandates. To present his findings in Turin			
22-6	Future PCC directions	Draft future PCC document for circulation to PCC for further comment/review	Addison	Before Turin 2023	On hold till 2023/2024 – discussion later in PCC program
22-7	International collaborations	Submit plans or paperwork for desired upcoming international collaborations	PCC Members	Before Turin 2023	Issued – none received
22-8	PCC description on IAPWS website	Update IAPWS website with more details and a refresh on the mandate of PCC	Addison	Before Turin 2023	Still in progress
22-16	Future PCC directions: radiation chemistry and radiolysis collaboration	Interface with PCAS on existing radiation chemistry activities and will propose a collaboration specific to radiolysis.	Yakabuskie	Prior to Turin 2023 meeting	Follow up with Dr. Yakabuskie.
22-17	Future PCC directions: radiation chemistry and radiolysis collaboration	Circulate existing PCAS proposal submission on radiation chemistry task group to PCC	Addison or Dooley		Not complete ... need to follow up
Summary of New Actions from PCC 2023					
23-1	Dew Point at low sulphur	Addison to discuss with Andy (GE) for addition to TG	Addison		
23-2	FFA decomposition products	Int'l Collaboration Project draft for EC submission	Yoshida		
23-3	FFA fouling on instrumentation	Int'l Collaboration Project draft for EC submission	Stansfield Cook		
23-4	Flue gas condensate	Submit white paper for publication + begin TGD draft	Fogh		
23-5	FFS in nuclear	Complete white paper draft for review	Fandrich	Dec2023	
23-6	Water use in hydrogen electrolyzers	Contact and coordinate papers for PEM / SOEC for sessions at ICPWS 2024	Addison Beucher Cook Dooley		

			Neilsen		
23-7	Corrosion products TGD	STG to review current comments and meet virtually to plan additions required	STG	Oct2023	
23-8	Instrumentation TGD	STG review and circulate comments / additions	STG	Oct2023	
23-9	White paper & Int'l Collaborations	Develop policy and process for promotion and release of these unofficial documents	Addison Dooley		
23-10	Internal structure of PCC and PCAS	Close collaboration needs to be reestablished and working relationship strengthened - discussion between WG Chairs needed	Addison		

List of Current IAPWS Special Task Groups (STG) for Technical Guidance Document Development Led by PCC

Task Group Name Corrosion Product Sampling
New TGD Intended but not at this stage
Revised TGD No
New White Paper Yes
STG Lead Dooley
STG Members Dooley, Thomsen, Nielsen, Vepsalainen – plus Addison, McCann. New members Skovbjerg, McAllister, Leidich

Task Group Name Flu Gas Condensation
New TGD Intended but not at this stage
Revised TGD N/A
New White Paper Yes
STG Lead Fogh
STG Members Dooley, Thomsen, new member Daal

Task Group Name Geothermal Steam Chemistry
New TGD Intended but not at this stage
Revised TGD N/A
New White Paper Yes

STG Lead Addison
STG Members Okita, Richardson

Task Group Name Electrode Boiler Chemistry
New TGD Yes
Revised TGD N/A
New White Paper N/A
STG Lead Addison/ Nielsen
STG Members Dooley, Vepsäläinen, Rziha

Task Group Name FFS for Nuclear Plants
New TGD Intended but not at this stage
Revised TGD N/A
New White Paper Yes
STG Lead Fandrich
STG Members Cook, Dooley, Stuart, Hater, Pringle, Ichihara, Hirano, Bengtsson, Duncanson

Task Group Name Instrumentation
New TGD No
Revised TGD Yes
New White Paper No
STG Lead Dooley
STG Members Stansfield, Nogales, Buchner, Addison, McCann

Task Group Name Steam Purity
New TGD No
Revised TGD Yes
New White Paper No
STG Lead Dooley
STG Members Svoboda, Leidich

Task Group Name Film Forming Substances
New TGD No
Revised TGD Yes
New White Paper No
STG Lead Dooley
STG Members Addison, TBC

Task Group Name Carryover
New TGD No
Revised TGD Yes
New White Paper No
STG Lead Dooley
STG Members Svoboda, Rziha

PCAS Led TGD Work with Support from PCC

Task Group Name Dew Point of Low Sulphur Gas
New TGD Intended but not at this stage
Revised TGD N/A
New White Paper Yes
STG Lead Okita
STG Members Addison, McCann