EXPIRED

**ICRN 19**

# IAPWS Certified Research Need - ICRN

## Improved Coolant Sampling and Analysis of Low Concentration Metals (Fe, Cu, Co, etc.)

The IAPWS Working Group Power Cycle Chemistry has examined the published work in the area of sampling insoluble impurities in water and steam, especially of metals and their oxides. Representative samples of such species are essential for the control of corrosion product transport in nuclear and fossil-fired power plants.

IAPWS recognizes that there is a requirement for work to be pursued in this field and has prepared this document to assist potential investigators in obtaining sponsorship. Specifically, requirements for isokinetic sampling, conditions governing the deposition of particles in sample lines, the influence of the corrosion film on the sample line surfaces, and precipitation of soluble corrosion products should be researched.

Although encouraging this work, IAPWS is not able under its statutes to provide financial support. The IAPWS contact can provide any further development information and will act as a liaison between research groups.

**Issued by the**
**International Association for the Properties of Water and Steam**

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### Background

It is of importance to obtain reliable measurements of corrosion product concentrations in water and steam because many power plant operating decisions rely on water chemistry information. In addition, to study corrosion and corrosion product transport, information obtained from the sample must correctly represent the system. Hence, a properly designed sampling system and an appropriate procedure must be employed to ensure representative sampling data.

The formation and transport of corrosion products in water/steam cycles have been major problems since the inception of thermal energy circuits. For instance, operating conditions in nuclear power plants must be closely controlled in order to minimise radiation dose rates. As far as corrosion products in water/steam cycle are concerned, they generally appear in both soluble and insoluble forms. This complicates the sampling procedures as the heterogeneous character of the system can easily lead to partial separation of phases resulting in non-representative sampling. This problem becomes more pronounced when high accuracy/precision of measurements is required.

To obtain representative samples from multiphase systems, “isokinetic” sampling is generally referred to. Isokinetic sampling is a technique for collecting all phases (particles, liquid droplets in vapor, vapor bubbles in liquid) in which the sampling device has a collection efficiency of unity for anything in the sampled fluid, regardless of velocity and direction of the instrument. This requires the fluid entering the sampling nozzle to have the same velocity vector (speed and direction) as the main stream. Isokinetic sampling has been widely recommended and applied; however, it is evident that this may not be necessary in every system [1, 2]. Moreover, isokinetic conditions at the sample nozzle may not be optimum for sample retrieval at the end of the sample line.

Phenomena occurring along sample lines (particle deposition, precipitation, etc.) are also of interest since, in reality, sample lines could be as long as 100 to 300 meters [3]. With this length of line, there is a considerable inventory of material that could be held up on the sample line walls. Some portions of this inventory can be returned to the sample flow by transients in flow or chemistry.

This subject has received attention in several publications and even specific procedural norms have been issued [4, 5]. However, the norms are not quite applicable in practice because of their high cost and inability to achieve reliable results. Most power utilities analyse the corrosion products at different places in the cycle and have different designs of equipment and use their own procedures. The reliability of the data is poor and outliers occur frequently.

### Research Needed

In general, corrosion product measurement can be divided into two main categories: sampling and analytical techniques. The former is to obtain representative samples, including a properly designed system and appropriate procedures, and the latter is to determine the concentrations as accurately as possible. This research work will be focused only on sampling technique described in detail as follows:

- Requirement of isokinetic sampling in water and steam systems:- phase separation during sampling depends on the sampling and stream velocities, density and viscosity of the stream, and particle properties. It is of interest to investigate under which conditions isokinetic sampling can be omitted and under which condition it is necessary.

- Particle deposition onto and release from sample line walls:- many parameters are involved in deposition and release. These include the effects of heat flux, thermophoresis, turbulence and point of zero charge (PZC). Most of these effects have been studied in water-recirculating loops [6, 7] but studies in a steam system are quite sparse. Deposition and release mechanisms of corrosion products in both water and steam sampling systems should be investigated.

- Evaluation of the relationship between Reynolds number and particle size - in particular conditions in which particles will settle down. In order to minimize deposition, controlling turbulence in the sample line seems advisable and, hence, hydrodynamic considerations are important. It should be noted that in high-temperature sampling, fluid properties change during cooling and flow regimes may be different before and after the cooler. The evaluation of the appropriate hydrodynamics should, therefore, be made along sample lines and/or sampling devices. This relationship follows from the previous paragraph.

- Precipitation and dissolution of corrosion products. If the fluid is oversaturated with particular species, then it is likely that precipitation of such species will occur. Conversely, if the fluid is undersaturated, dissolution will take place. It should be noted that these processes should not be considered in terms of thermodynamics only; kinetics is also important. This is due to the fact that the system may not reach equilibrium and, hence, kinetics controls the rates.

Nowadays, determination of low concentrations of metals in water/steam cycles with a high degree of precision is required in power plants. This is believed to improve reliability of measurements and consequently obtain a better control of power plant operation. However, it should be pointed out that economical feasibility cannot be overlooked. An acceptable precision of low concentration determination should be identified.

An investigation on sampling techniques and procedures will improve analyses of low concentration metals. The effects of different parameters will be considered and verified. A general agreement on system design and operating procedures for sampling would be of great value to industry.

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**ICRN Issue Date:** September 2006

**ICRN Expiration Date:** September 2009

## References

1. Hinds, W.C., *Aerosol Technology: Properties, Behavior and Measurement of Airborne Particles*. 1982, NY: John Wiley & Sons.
2. Svoboda, R., *et al. Trace Analysis of Corrosion Products by Integrating Sampling Techniques*. in *Water Chemistry of Nuclear Reactor Systems 3*. 1983. Bournemouth, UK: BNES.
3. 1009951, Evaluation of Fuel Clad Corrosion Product Deposits and Circulating Corrosion Products in PWRs. 2004, EPRI and Westinghouse Electric Company LLC.
4. ASTM D1066-97, Standard Practice for Sampling Steam. 2001.
5. ASTM D3770, Standard Practice for Sampling Water from Closed Conduits. 1999.
6. Basset, M., *et al.*, *The Fouling of Alloy-800 Heat Exchange Surfaces by Magnetite Particles.* The Canadian Journal of Chemical Engineering, 2000. **78**: p. 40-52.
7. Cossaboom, J.L. and D.H. Lister. *The Fouling of Alloy-800 Heat Exchanger Tubes by Nickel Ferrite*. in *Intl. Conference on Heat Exchanger Fouling and Cleaning - Challenges and Opportunities*. 2005. Kloster Irsee, Germany.