EXPIRED

IAPWS Certified Research Need - ICRN 5

Origin, Behavior, and Fate of Organics in the Power Cycle

The IAPWS Working Group - Power Cycle Chemistry has examined the published work in the area of the behavior of organics and their decomposition products in power cycles which is of interest to the electric power industry.

IAPWS recognizes that there is a requirement for work to be pursued in this field and has prepared this document to assist potential investigators obtain sponsorship. The knowledge of the origin, composition, behavior, and fate of organics in the power cycle is very important when investigating the appropriate measures which could influence the decrease of the first condensate pH and also turbine disk and blade failures. Extended studies have been performed in some partial areas, but the comprehensive knowledge of the fate of organics in plant cycle is not available. The research needs are a series of thermal degradation and distribution experiments of all organics which could exist in the power plant cycle. The temperature range of interest is ambient up to 650°C.

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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IAPWS

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The knowledge of the behavior and fate of organics in power cycles is of great importance for utilities and the manufacturers of major power plant components. The hydrothermal decomposition of organics leads to products which are thought to endanger some specific plant cycle areas, particularly disks and blades of steam turbines. To understand the behavior and fate of organics in the cycle, it is first necessary to have comprehensive knowledge of their origin and composition.

Significant research has been carried out by geochemists on the kinetics of decomposition of natural organic matter. It is our intention to extend this work to cover the conditions encountered in steam-condensate cycles in order to identify the major breakdown products and determine their distribution throughout the cycle.

1. Origin and Composition of Organics in the Power Plant Cycle

Organics can enter into plant cycles in different ways. The most important organics ingressing into plant cycles are:

- Natural organic matter such as fulvic and humic acids, present in raw water that may enter through condenser leakage or slip through the makeup water treatment plant. The substances may be described as heterogeneous mixtures of molecules which, in a given soil, range in molecular weight from as low as several hundred to perhaps over 300,000 daltons. They contain free and bound phenolic groups, quinone structures, nitrogen and oxygen as bridge units, and carboxylic groups variously placed on aromatic rings.

- Industrially produced organic substances that are present as pollution in raw water and enter into the plant cycle in the same way as the natural organic matter. The most important of these substances are organics containing halogens, sulphur, nitrogen, and phosphorus. Examples are: chlorinated aliphatic and aromatic hydrocarbons, alkyl and alkyl aryl sulfonates, amines, esters of phosphoric acid, and organophosphonates such as aminotri(methylene phosphonic acid), 1-hydroxy-ethylidene- 1, 1-diphosophonic acid, and 2-phosphonobutane-1,2,4-tri-carboxylic acid.

- Resin extractables and leachables, resin fines, and organic precoat and precoat overlay materials enter into plant cycles via makeup water treatment and condensate polishing installations. The compounds derived from ion exchange resins, vary with resin type and may contain either sulphur, nitrogen, or chlorine. Examples are sulfonated aromatic compounds (monomers) and respective oligomers and polymers.

- Organic plant cycle additives (e.g. ammonia, hydrazine, carbohydrazide, morpholine, cyclohexylamine, diethylhydroxylamine, isoascorbic acid, hydrochinone).

Beyond this initial list, other sources of organics are conceivable. Here, as examples, the air inleakage and the plant cycle contamination with lubricating oils and greases as well as with fuels are worth mentioning.

2. Behavior and Fate of Organics in the Power Cycle

As a rule, the hydrothermal decomposition of organics in plant cycles leads to the production of low-molecular-weight organic acids (e.g. formic and acetic acid), carbon dioxide, and perhaps some other low-molecular-weight compounds. According to the chemical composition of the respective organic molecule, strong inorganic acids (e.g. hydrochloric and sulphuric acid), aminoalcohols, amines, ammonia, and a number of other products may be formed.

Many of the organics decomposition products markedly affect the plant cycle chemistry and, importantly, may contribute to the failure of major plant components, such as turbine blades and disks.

3. Needed Research Activities

The first need is a critical review and evaluation of literature and laboratory determinations of decomposition reactions and thermal stability of all possible relevant compounds. The second need, following this theoretical work, is to perform hydrothermal decomposition experiments under the operating temperature (up to 650°C) and pressure conditions (up to 250 bar) and physico-chemical conditions of fossil and nuclear cycles and to identify all products of decomposition. In many cases, the appropriate analytical techniques have to be developed.

The decomposition products of organics that are stable under plant cycle conditions may influence the overall plant cycle chemistry and the composition of the in-situ environment in some plant cycle areas. For this reason, the third need is an experimental study of the distribution behavior of such compounds between water and steam. Some of the decomposition products possibly may have other properties which could be of interest. Such a property would be, for example, the ability to form stable complexes with metal ions. Corresponding investigations are desirable.

The establishment of mass balances of organic species around the fossil and nuclear cycles is also needed. An assumption is, that for this purpose new sampling and analytical techniques may have to be developed or at least that the existing sampling and analytical techniques have to be subject to further development.

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