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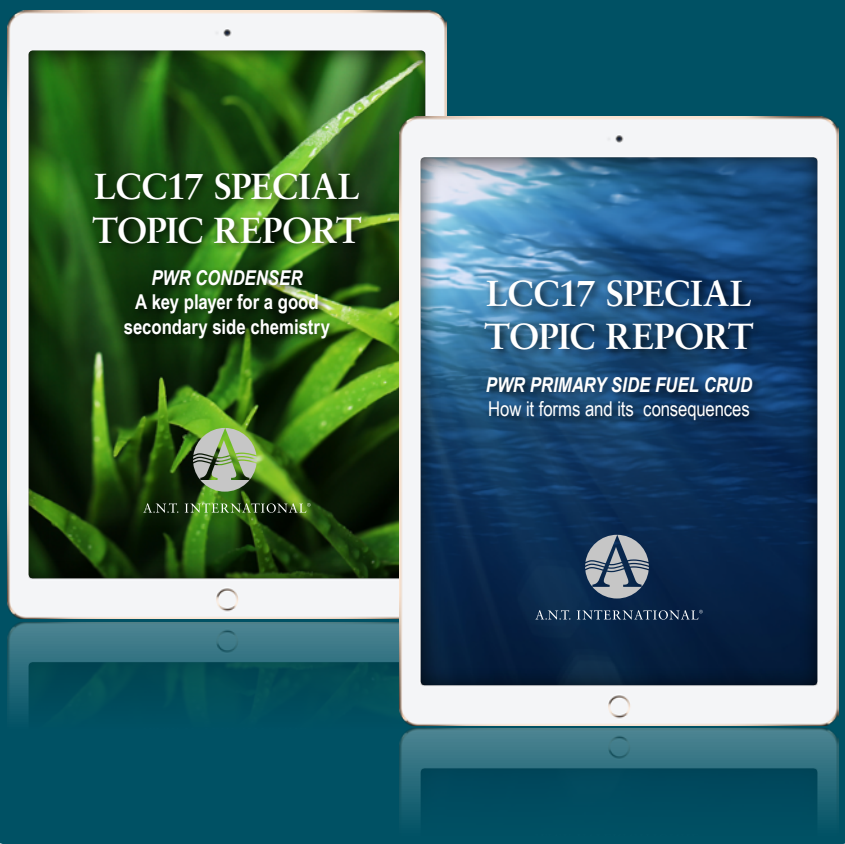
Boosting your Excellence through Knowledge and Training



A.N.T. INTERNATIONAL®

LCC™

LWR Chemistry and Component Integrity Programme

The annual LCC Programme is focused on reactor coolant, secondary chemistry and material issues and open to nuclear utilities, manufacturers and vendors, research and engineering organisations as well as regulatory agencies. In the LCC16 Programme, currently 18 organisations in North America and Europe are members. The Programme was started in 2004.

Deliverables

A.N.T. International will provide the LCC Members with the following:

- **Searchable electronic report version with the following contents:**
  - » High-resolution pdf files with complete LCC Annual Reports in colour.
  - » The files can be copied to a company server, and be available to everyone with access to the server.
  - » The contents from the Annual Reports in pdf-format can be printed. Also, the contents from the pdf-files can be copied and pasted electronically into other documents, e.g. Word files.
  - » All figures and tables with A.N.T International copyright can be used by the member both internally and externally provides that the source is provides in the caption.
- **A Seminar will be held in Madrid, in April 2022, to present the results of the LCC Programme. The number of full-time employees per Member that may attend the seminar is limited to eight (8) people per organization.**
- **Before the seminar, you will have access to:**
  - » The complete LCC Reports in digital format (PDF).
  - » The contents of all the seminar presentations in high-resolution PDF format.
  - » Prerecorded mp4 files of the presentations
- **The language of the LCC Programme will be English.**
- **The authors will be available for consulting throughout the year. A few telephone or e- mail consultations requiring no additional work are provided at no additional cost to Members.**

"The long experience of the LCC Expert Team provides useful information for 'sunny and cloudy days' of achemist's job!"

MICHAEL BOLZ
NPP Philippsburg

"A.N.T. International provides excellent material for education, this supports the very important transfer of knowledge in times when alternation of generation becomes a problem in many nuclear power plants."

BERNT BENGTSSON
Vattenfall

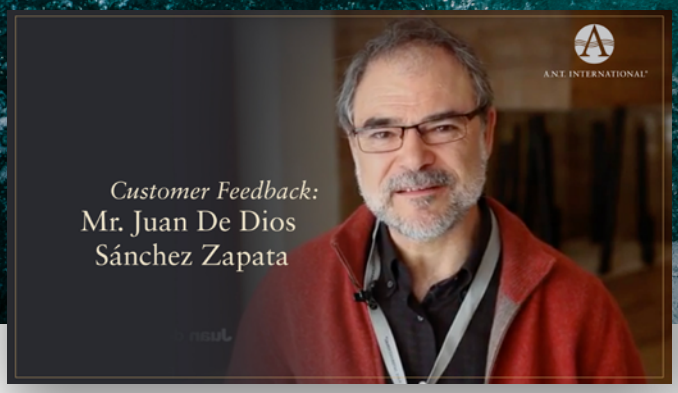
LCC Programme Content and Description

Nuclear utilities must reduce costs for operation, maintenance and fuel, keep the highest level of safety and lowest possible level of radiation exposure to employees and the public and minimize environmental impact of liquid and solid effluentsand wastes.

Emphasis is put on safety, longer fuel cycles, higher burn up of fuel, increased fuel duty with more nucleate boiling in Pressurised Water Reactor (PWR's). Plant power up rates as well as more technical issues like Axial Offset Anomaly (AOA also called Crud Induced Power Shift/CIPS), Stress Corrosion Cracking (SCC) all point to the increased importance of high quality water chemistry and control and safe long term operation of the Nuclear Power Plants.

It is our goal that the LCC Programme shall assist the LCC Members in meeting all these water chemistry and material related challenges in the most efficient way. This Programme reviews and evaluates the developments and trends in the Light Water Reactor (LWR) primary coolant and secondary side chemistry and structural materials technology (excluding fuel materials). This is accomplished by identification of relevant information and a discussion of its significance for the Programme. The Programme reviews all relevant information through publications and international conferences and, when necessary, comments and background information are added.

Additional benefits for the LCC Members can be seen in that the Members gain an increased understanding of power plant water chemistry and material integrity to facilitate more efficient plant operation. Furthermore, the LCC Members can be assisted in the training and education of a new generation of chemistry and material experts in their organizations.



The overall objectives of the LCC Programme are to enable the LCC Member to:

Increase understanding of reactor water chemistry related to a successful plant operation and continued integrity of Reactor Coolant System (RCS) materials while keeping radiation exposure low

Guide the plant operators to apply adequate PWR secondary side chemistry for safe, economical and environmentally friendly plant operation with high availability and without significant steam generator degradation or fouling problems or carbon steel Flow Accelerated Corrosion.

Improve plant operation and chemistry control and monitoring

Assist in the training and education of a new generation of chemistry and materials experts.

Establish an independent meeting point for experts to enable free and critical discussions and experience exchange

These objectives are met through critical review and evaluation of the most recent data related to reactor water and secondary side chemistry, identification of the most important new information, and discussion of its significance in relation to water chemistry now and in the future.

The evaluations are based on the large amount of non-proprietary data presented at technical meetings and published in the literature with added point of view of LCC experts

"One of the main advantages with these seminars is the contacts you can make with the experts"

JOLANDA CAPPAERT-DE VOS
EPZ

"Excellent presentation material given in a thoroughly professional manner. Excellent interaction with regard to answering the questions raised by the audience.

CHISTOPHER SMITH
Rolls-Royce

LCC17 Programme

The following reports will be delivered in the LCC17 Programme:

- **PWR condenser: a key player for a good secondary side chemistry**
- **PWR primary side fuel crud, how it forms and its consequences**

Presentation without Reports will be prepared within the LCC17 Programme as follows:

- **Presentations by:**
  - » Samson Hettiarachchi
    - o NPP Fuel Performance in Challenging Water Chemistry and Operational Conditions »
  - » Jiaxin Chen
    - o Corrosion kinetics of nickel base alloys »
  - » Daniel Parrat
    - o Radiochemistry »
  - » Klas Lundgren
    - o Sources of Mo-93 in operational waste from BWR and PWR – Impact of materials selection and water chemistry conditions

At the LCC17 Seminar, the Reports will be presented and are described more in the following.

"An excellent seminar, it was very useful for me"

JOLANDA CAPPAERT-DE VOS
EPZ

"I learned a lot of chemistry in a plant"

MAGDALENA WILZYNSKA
KKL

LCC17 Reports

PWR condenser: a key player for a good secondary side chemistry

There is no good secondary side chemistry and, there is no good plant availability without a condenser in good condition. Whatever the chemists 's skills, getting a good secondary side chemistry with a leaking condenser is most often a lost challenge

This means that knowing the secondary side chemistry guidelines is not enough for a plant chemist to run a plant (from the chemistry perspective), he/she also has to know what kind of failures a condenser can suffer from. These failures can be materials failures, failures resulting from a poor design of failures stemming from improper operation.

So far, A.N.T. International has given little attention to condenser 's condition and this report, entitled "PWR condenser: a key player for a good secondary side chemistry" aims at filling this gap.

After some design consideration, this report presents why having a condenser in good condition is paramount for reliable plant operation. Following, the reader will find an extended summary of condensers' field experience, including a list of all the areas where failures have occurred these last decades along with related remedial actions, then, how to monitor condenser 's operation and also how to maintain a condenser.

This report intent is to help plant chemists getting a broader picture of secondary side chemistry by drawing their attention to the stakes of having a condenser in good condition.

CONTENT

PWR primary side fuel crud, how it forms and its consequences

The presence of deposits on fuel clad (fuel crud) can impact the safe and efficient operation of light water reactor systems. This report will discuss the topic of fuel crud in PWR systems, starting with a brief history of reactor observations of fuel crud. The report will then discuss what is fuel crud and from where does it originate. It will cover the basic mechanisms for fuel crud deposition and how these relate to operational chemistry and core thermal hydraulics design.

The presence of fuel crud can lead to crud induced power shifts (CIPS), formally referred to as axial offset anomaly, the mechanism for CIPS and strategies for avoiding it will be discussed. Similarly crud may lead to crud induced localised corrosion (CILC) of the clad, how this can occur and how to avoid CILC events will be discussed.

The relationship between the presence of crud, limits on operational coolant Zn, Li and other impurity levels will also be covered.

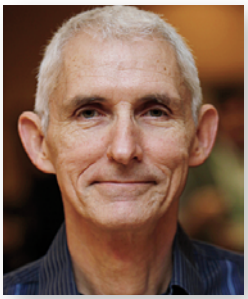
The general aim of this document will be to provide the reader with a broad understanding of this phenomena, how it relates to plant primary circuit chemistry, plant material choices and core design, as well as familiarising the reader with available literature on the topic.

CONTENT

LCC17 Lecturers

Dr. Samson Hettiarachchi has 40 years of experience as a college lecturer, researcher, innovator and a technologist. He has held a variety of technical positions at GE Nuclear Energy as Chief Engineer/Physical Sciences, Chief Technologist/Chemistry, Engineering Fellow and Principal Engineer prior to his retirement from GE in February 2011. Prior to joining GE, he held the position of Electrochemist/Senior Electrochemist at SRI International (formerly) Stanford Research Institute) and the position of Lecturer/Senior Lecturer in Chemistry at the University of Colombo, Sri Lanka. Two of his innovations at GE Nuclear Energy, NobleChemTM and On-Line NobleChem are widely used in the US, Japan, Spain, Mexico and Switzerland to extend the life of Boiling Water Nuclear Reactors. Dr. Hettiarachchi's research experiences include Physical Chemistry, Electrochemistry, Surface Chemistry, Catalysis, Corrosion and Mitigation of materials, Battery Technology, Sensor Technology, and In-situ Generation of Nano-particles. He has worked in the nuclear power industry related work for 30 years. His specific experiences in this industry include, Development of ECP sensors, ECP monitoring, High Temperature pH Measurements, Zeta Potential Measurements, HWC Benchmark Tests, Water Chemistry Guidelines, Dose Reduction, Fuel Corrosion, SCC Mitigation, NobleChem Applications, On-Line NobleChem Applications, Inspection Relief Criteria Development, and Plant Chemistry/Materials Education and Training. For many years he hasparticipated in EPRI BWRVIP Mitigation Committee Meetings and several IAEA Meetings. He has over 100 publications in International Journals and International Conference Proceedings and holds 29 issued US patents. He has been a peer reviewer for the Corrosion Journal and the Journal of Nuclear Science and Engineering.

Dr. Jiaxin Chen joined Studsvik in 1997 and currently works as Senior Specialist in fuel crud and oxide characterisation in Studsvik Corrosion and Water Chemistry Laboratory. He was adjunct professor at Department of Physics, during 2014-2016, and now at Department of Chemistry and Chemical Engineering (from 2020), Chalmers University of Technology. His recent research interests include quantum chemistry study on coolant zinc interaction with oxides; microstructural characterization of fuel crud and solids in LWR coolant; corrosion kinetics of reactor material surfaces in LWR primary coolant; characterisation of radioactive deposit on LWR piping surfaces; stability of neutron absorber materials in reactor coolant In the field of PWR fuel crud, he and his colleagues at Studsvik have made some significant experimental findings that are of high value for the industry.



Mr. François Cattant graduated in chemical engineering in 1974 and joined Electricity of France (EDF) in 1975 as chemist engineer at the chemical department of the corporate laboratories (Plants Operation Division). At that time, he was involved in power plants water and steam conditioning. Up to 1995 he worked in the following technical fields as an expert in the following areas:

- **Failure root cause analysis of gas-cooled reactors components, including fuel**
- **Water & steam chemistry, chemical cleaning and NDE for fossil fired stations**
- **Failure root cause analysis of nuclear power plants irradiated or contaminated parts & components and reactor pressure vessel (RPV) irradiation programs monitoring**
- **Examination of Dampierre 1 retired steam generator, to the examination of RPV head penetrations, to the study of thermal embrittlement, to the analysis of wear.**

Between 1995 and 1998 he was loan-in to the Nuclear Maintenance Application Center at EPRI Charlotte (NC, USA). He was involved in various maintenance guides such as those of pumps or diesel generators. He also acted as EPRI expert for the examination of Ringhals 3 retired steam generator.

In 1998 he moved back to France, at the R&D Materials and Mechanics of Components department where he stayed until his retirement in 2009. He served there as scientific advisor and senior engineer. His area of expertise was again chemistry, corrosion, and metallurgy, with special attention to primary water chemistry, source term reduction, primary water corrosion (Alloys 600/182/82, SSs), PWSCC mitigation and repair, fuel cleaning, innovation strategy. He also served as the EDF representative to the EPRI Materials Reliability program. From 2004 to 2008, he was the President of the "Materials, Non Destructive Testing and Chemistry" section of the "French Nuclear Energy Society". During his career he made many presentations and papers in international conferences and scientific journals.

In 2010, he was sponsored by the MAI to write a "Handbook of Destructive Assays", a 1100 pages' document putting together extended summaries of hundreds of destructive examinations performed on LWRs' NSSSs, in France, US, Japan and Sweden.

Mr. Klas Lundgren graduated 1973 in M.S Engineering Physics, Chalmers University of Technology, Gothenburg, Sweden. Joined ASEA-ATOM (later ABB Atom) in 1973. Was one of the founders of ALARA Engineering in 1995, which from 2008 was incorporated in Studsvik Nuclear. Klas holds presently, 2021, a position as Senior Specialist in radiation technology at Studsvik Nuclear.

Main areas of interest have been:

- BWR water chemistry, radiation and materials - sampling and analysis, cleanup systems, condensate, feed and reactor water chemistry, gamma scanning and radiation

measurements, Hydrogen Water Chemistry, radiochemistry evaluations, ALARA reviews in European and US BWRs, computer models for activity buildup in BWRs, post-accident analysis, computerized plant chemistry and activity data systems, radioactivity monitoring systems, radwaste and offgas systems. Plant-Life-Extension (PLEX)

- PWR water chemistry and radiation – Radiolysis chemistry, activity build-up, safety analysis and source terms
- Radiation shielding and radiation technology - computer code development, shielding design of BWRs and waste handling facilities, neutron transport calculation for activation and criticality analysis, radiation surveillance at power plants, reactor decommissioning analysis, safety analysis reports. shielding and neutron activation calculations of proton cyclotrons.

Dr. Jim Hensaw is a chemist with a PhD in theoretical chemistry, developing methods to solve the time dependent Schrodinger equation. Jim has extensive experience in modelling radiation chemistry phenomena and has worked on topics relating to nuclear plant chemistry and nuclear reactor water/gas chemistry for over 30 years. Initially employed at Harwell Laboratory by the United Kingdom Atomic Energy Authority 1986 he retired from the UK National Nuclear Laboratory in 2020 as its leading reactor chemist. Jim is a recognised world expert in chemistry and in particular radiation chemistry in nuclear reactor systems. Over the years he has also spent much of his time studying material and activity transport issues in a range of different reactor systems and has a good understand of how reactor chemistry impacts material corrosion and fuel behaviour. Working with organisations around the world he has investigated problems in BWRs, PWRs and gas cooled systems and helped optimise plant operations. In fact many of these reactors currently utilise software for optimising their chemistry operations that he helped develop.

Dr. Daniel Parrat is research engineer and was an International Expert at the Nuclear Energy Division of the CEA. He has been working in the field of nuclear fuel behaviour in Light Water Reactors and was responsible of fuel irradiation programs dealing with the release of fission products out of failed rods in normal, incidental and accidental conditions. He developed new methods and techniques for detection and characterisation of failed LWR fuel rods in power plants, for which he won a CEA prize. He served several times as a lecturer for training sessions or workshops organised by the IAEA or the French INSTN. He has been involved in the definition of fuel experimental programmes for the future Jules Horowitz material testing reactor (JHR) and in the design of its experimental capacity: irradiation hosting systems, non-destructive examination benches and analysis laboratories in support.

Price and Terms of Payment

The fixed nominal price for the LCC Membership appears in the associated Proposal.

Terms and Conditions

The term of LCC17 Programme starts from the date of the purchase order and lasts 12 months onwards.

ANT International shall exercise its best efforts to meet the objectives in this assignment and shall apply to the work professional personnel having the required skills, experience and competence. If the assignment is found to be significantly deficient by the customer within 6 months of its completion, A.N.T. International shall modify the work done within this assignment in such a way that it will become satisfactory to the customer. This modification shall be done without incurring any additional costs to the customer. The total amount of such additional costs due to the modification shall be limited to be less or equal to the amount originally paid to A.N.T. International for this assignment. It is understood that AN.T. International is not responsible for any damage, incurred to the customer, their employees, or their plants or to a third party due to the use of the information or the recommendations given within this assignment.

The compiled information and the conclusions, as a result of this work, may be used by the purchasing party for its own use for any purpose provided that the source is given. A.N.T. International retains the rights to the compiled information and the conclusions for other uses.

Nuclear Liability

A.N.T. International and its sub-suppliers, including also suppliers of information and services, of every tier and kind, and everyone engaged by any of them, shall have no liability whatsoever (irrespective of negligence or gross negligence) for any damage or loss whatsoever (including also consequential and indirect loss) resulting from a nuclear incident (as such term is defined in the Paris Convention on third party liability in the field of nuclear energy, as amended from time to time). This shall apply for damage or loss suffered by third parties or the owner and for damage and loss to the nuclear installation, on site property and any other property of any kind, and until the nuclear installation has been decommissioned and irrespective of any termination or cancellation of the proposed work.

Insurances of the owner and of others in respect of a nuclear incident shall exclude any right of recourse against the supplier and his sub-suppliers of every tier and kind.

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