LCC™

LWR Chemistry and Component Integrity Programme

The LCC14 deliverables.

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 LCC13 Programme, currently 16 organisations in North America and Europe are members.
The Programme was started in 2004.


A.N.T. INTERNATIONAL®

Deliverables

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

- Immediate download of high-resolution LCC Annual Report and PDF files in colour.
  - » The files can be copied to a company server, with full read access for everybody with access to the server.
  - » The contents from LCC Annual Report and the Special Topic Reports can be printed. Also, the contents from the pdf-files can be copied and pasted electronically into other documents, e.g. Word files.
- The file(s) of the LCC Annual Report will be provided before the Seminars (see below).
- Optional reports printed in four-colour. The printed LCC Special Topic Report and the Annual Reports will be provided as soon as they are printed with the aim of delivery before the Seminar in March.
- A Seminar will be held in Europe to present the results of the LCC Programme. The number of full time employees per Member that may attend meetings is limited to eight (8) people per organisation. 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 a chemist's job!"

MICHAEL BOLZ
NPP Philippsburg

Find more feedback at: www.antinternational.com/LCC

LCC14 Programme

Annual Reports will be prepared within the LCC14 Programme as follows:

- Key Emerging Issues and Recent Progress Related to Structural Materials Degradation
- Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion, PWR/VVER/CANDU Nuclear Power Plants
- Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion, BWR Nuclear Power Plants
- Key Emerging Issues and Recent Progress Related to Dose Rate Reduction

Presentations without Reports will be prepared within the LCC14 Programme as follows:

- Techniques in Analytical Chemistry at Nuclear Power Plants
- Primary Side Sampling Systems
- PWR Dose Rates and Mitigation Tools

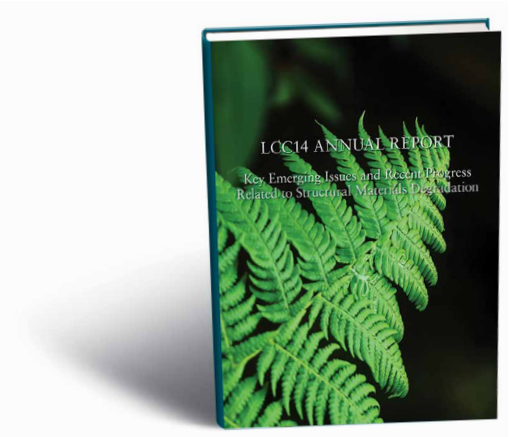
Presentations from invited speakers, as follows:

- Decommissioning Preparation at Mühleberg. Chemistry Transition
- Another presentation to be defined

At the LCC14 Seminar, the Annual Reports will be presented, described more in the following.

LCC14 Reports

Reports on Key Emerging Issues and Recent Progress Related to Structural Material Degradation



During operation, the materials used for the construction of components react with light water reactor environment and cause component degradation, including cracking at welds and piping. Such degradation is due to irradiation, corrosion, fatigue, and other damage mechanisms, and has remained a severe operational challenge for utilities. Details on such degradation are regularly reported and published in scientific journals and at utility workshops and conferences. Foremost in the latter category are those organised since 1983 by NACE, TMS, ANS and CNS in the Environmental Degradation of Water Reactor Materials.

The Annual Report will contain highlights from the 18th International Conference on Environmental Degradation of Materials in Nuclear Power Systems Water Reactors, which was held in Portland, Oregon in August 2017. It will cover PWRs, VVERs, CANDUs and BWRs.

Over 150 papers were published at this conference and this report covers:

- Boiling water reactors and pressurised water reactors;
- Primary and secondary side degradation of nuclear power plant components;
- Water chemistry of boiling water reactors and pressurised water reactors;
- Irradiation effects and irradiation assisted stress corrosion cracking;
- Reactor pressure vessel embrittlement and environmentally assisted cracking;
- Emerging issues for new and extended reactor operations;
- Fuel, spent fuel, and radioactive waste disposal;
- Plant operating experience.

Reports on Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion

The 21st Nuclear Plant Chemistry (NPC) International Conference, which started in Bournemouth (UK), held every other year, will be held in San Francisco (USA) 9-14 September 2018. It is the most important conference related to chemistry in Nuclear Power Plants, and covers many new results in this area. It provides a forum for utility personnel, engineers, scientists, university researchers, research institutes, and service organisations to inte-ract and address the challenges faced by the nuclear power industry.

The key information presented at this Conference will be covered in two separate Reports: One on PWRs, VVERs, CANDUs, PHWRs and auxiliary systems issues. The other on BWRs and and various other subjects.

Report on PWRs, VVERs, CANDUs, PHWRs

This first report on PWRs, VVERs, CANDUs and PHWRs, eventually SMRs will not only summarise but analyse the results to assess in which specific situation the results are applicable and give the point of view of expert of ANT International expert.

Instead of giving a short summary of each paper presented at the conference, the report will cover and the key facts, either new or of significant interest for LCC customers. This is of significant interest, to discuss how to consider different presentations that may sometimes give contradictory or conflicting results. A past example explained for which PWR units hydrogen concentration in the Reactor Coolant System should be increased or decreased, or kept in historical range. The advantages, disadvantages, questions or limitations of new solutions will be explained.

More specifically, the following subjects from oral and poster sessions from the Conference may be covered in this report, depending on the existence and interest of the papers: PWR, VVER & CANDU/PHWR Operating Experience Primary coolants, including dissolved hydrogen, pH, lithium, boric acid, enriched boric acid, potassium, ammonia, zinc, activity buildup, and radiation control.

- Chemistry and Fuel Performance as Applied to PWR, VVER & CANDU/PHWR
  Effects of chemistry on fuel performance, crud related fuel performance and failure issues – including crud induced localised corrosion, shadow corrosion, tramp uranium and fission products.
- Pressurised Water Scientific Studies
  Fundamental and laboratory studies, computer modelling and analyses.
- LWR Secondary Water Chemistry (Steam Cycle)
  Steam – water system treatment, steam generator degradation, sludge management, lay-up optimisation, flow-accelerated corrosion, corrosion product transport, amines, filming amine, and dispersant, fouling mitigation.
- Life Time Management and Plant Ageing of PWR, VVER & CANDU/PHWR
  Chemistry and corrosion issues related to lifetime management and long term operation.
- Auxiliary Systems, Water and Waste Treatment System as Applied to PWR, VVER & CANDU/PHWR
  Water purity control, chemistry control in auxiliary systems, monitoring technologies, performance metrics, scale mitigation, microbiological control, waste water management.
- Maintenance (Decontamination) as Applied to PWR, VVER & CANDU/PHWR
  Decontamination, chemical cleaning (steam generator, heat exchanger), fuel cleaning, water chemistry control during long term shutdown.
- Chemistry for Nuclear New Build: Water chemistry plans for new nuclear power plants, commissioning strategies, passivation optimisation and experience, developments in LWR plant design and materials, and improvements and challenges for the operation of new plants such as expended cycles.
- Future Trend And New Development/Scientific Basis for PWR, VVER, CANDU/PHWR, SMR (Small Modular Reactors) and FBR (Fast Breader Reactors)
  Chemistry developments for future reactor systems and other advanced systems.
- Chemistry Optimisation Programs and Compliance Management – Development and pre-implementation assessment of Utility Chemistry Optimisation Programs, and Chemistry Program Management, audits, sampling, monitoring, analysis programs.

Report on BWRs

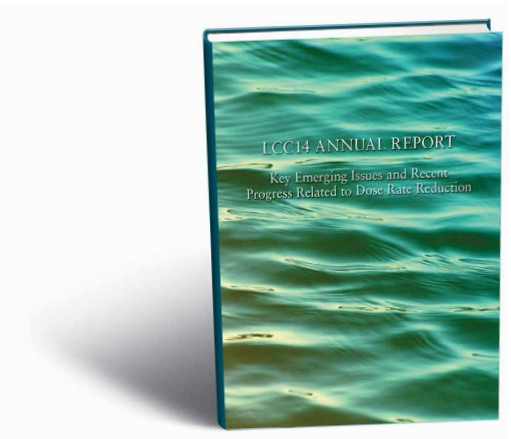
The second report summarising the BWR related papers and various other subjects is designed to provide updated information with the author's critique and analysis for the benefit of the LCC customers. The report is expected to be a comprehensive summary document incorporating the latest information on BWR water chemistry and decommissioning that would benefit the operators and regulators, and those who have not been able to attend the NPC 2018 Conference.

The following oral and poster sessions will be covered in this report:

- BWR Operating Experience
  Hydrogen water chemistry, noble metal chemical addition, zinc addition, materials corrosion, radiolysis, combustible gas management, activity build-up, and radiation control.

- Life Time Management and Plant Ageing as Applied to BWRs
  Chemistry and corrosion issues related to lifetime management and long term operation.
- Chemistry and Fuel Performance as Applied to BWRs
  Effects of chemistry on fuel performance, crud related fuel performance and failure issues – including crud induced localised corrosion, shadow corrosion, tramp uranium and fission products.
- Auxiliary Systems, Water and Waste Treatment System as Applied to BWRs
  Water purity control, chemistry control in auxiliary systems, monitoring technologies, performance metrics, waste water management.
- Chemistry Optimisation Programs and Compliance Management as Applied to BWRs
  Development and pre-implementation assessment of Utility Chemistry Optimisation Programs, and Chemistry Program Management, sampling, monitoring and analysis.
- Boiling Water Reactor Scientific Studies
  Fundamental and laboratory studies, computer modelling and analyses.
- Maintenance (Decontamination) as Applied to BWRs – Decommissioning
  Decontamination, water chemistry control during long term shutdown.
  Decommissioning related to all types of plants.
- Future Trend and New Developments/Scientific Basis as Applied to BWRs and MSR)
  Chemistry developments for future reactor including supercritical water, GEN IV MSR (Molten Salts Reactors), and other advanced systems.

Reports on Key Emerging Issues and Recent Progress Related to Dose Rate Reduction



This 2018 conference is a reschedule of the "2017 EPRI Source Term and Radiation Field Reduction Workshop & Exhibition" which was cancelled by inclement weather in the southern U.S. in the fall of 2017.

This conference will address both theoretical and practical dose rate reductions for BWRs and PWRs. The previous conference information, which was held in 2013, was presented at LCC9 in Bilbao, Spain.

In the past this conference has covered such topics as the current industry wide state of dose rate reduction efforts, plant experiences, theoretical modelling of corrosion product transport and their contribution to plant dose rates. New techniques for measuring dose rates and determination of the individual radionuclide contributors are also expected.

This paper and presentation will be of interest to both utility personnel and regulators by providing them with the current information on dose rate and dose reduction techniques.

LCC14 Presentations without Reports

Additional presentations will be given on the following topics.

Techniques in Analytical Chemistry at Nuclear Power Plants

This presentation addresses the "business needs" for analytical chemistry in Duke Energy's three PWR stations. It describes the preparation of laboratory methods used to analyse Adenosine Triphosphate (ATP) and lithium in a boric acid matrix.

Laboratory methods are developed by either General Office Chemistry personnel or GO/plant personnel. The laboratory methods contain all the information necessary for the sites to write their own analytical procedures in their forma. The laboratory methods also contain the necessary quality control information.

A nuclear power plant laboratory is a working laboratory as opposed to a research laboratory. As a result, it is not necessary to purchase expensive instruments and train chemists to analyse samples to the lowest level possible. The analytical techniques can be appropriate to support the needs of the users of the plant analytical data. This presentation provides information on the analytical techniques used, the limit of detection and the ranges that Duke Energy determined were adequate for their business needs.

The ATP analysis is applicable for systems requiring ATP analysis, usually closed cooling water, for monitoring microbial biomass activity. ATP is a high energy compound that serves as the principle carrier of biologically useful energy in all living cells. ATP is produced only in living cells. The amount of ATP within a cell is proportional to cell size and cell activity. When cells die, ATP within the cell declines. Therefore, the higher the ATP activity, the more bacteria are in the system.

The lithium analysis is used to analyse lithium in primary systems where boric acid interferes with the lithium analysis.

This presentation will be of interest to plant chemists involved in analytical activities. Regulators may also benefit by gaining insight into plant activities.

Primary Side Sampling systems

Adequate water chemistry control program is indispensable for operational performance of the plant systems and components to avoid any significant corrosion, radiation field pro-blems. The bases for the water chemistry programme are the results of sampling analysis, which are gained by using the sampling and monitoring system. However, in almost in all PWR plants that were built before 1990s, the design criterion for sampling system in Reactor Coolant System (RCS) was to deliver a representative liquid sample for soluble boron and soluble fission products samples without exposing the operator to excessive radiation. The RCS sampling systems were usually not designed to obtain representative samples of trace corrosion product species or radio nuclides. The sample lines installed are long, have inadequate sampling nozzles, and are tubes of small diameter, which have a high ratio surface/volume, so that significant interaction can occur between sample medium and oxide layers on the sample line surface. This interaction and

also uneven temperature distribution over the sampling line length can significantly affect the sampling composition.

Since 1990s, based on achieved field experience, continuous improvements in sampling system design were done in new built PWR and BWR plants to get representative samples. Accordingly, these guidelines were used to design the sampling systems for the new PWRs and BWRs. Especially intensive discussions were performed with respect to need for isokinetic sampling techniques. Furthermore, monitoring techniques and equipment were continuously improved in order to meet the water chemistry guideline requirements more adequately and yield more cost-effective results for utilities.

This presentation will provide a review of the information extracted from corresponding publications. The need or not for isokinetic sampling will be discussed; all possible parameters that may bias the sampling representativeness will be described. In addition, it will summarise the sampling system designs used in different type of nuclear power plants in European countries and in North America. In doing so, it will draw upon achieved field experiences with the respective sampling systems.

PWR Dose Rates and Mitigation Tools

There is a general consensus regarding the mechanism of activity build-up in PWRs. The out-of-core materials are releasing corrosion products, which are transported to the fuel and become activated. They are released back into the coolant and may deposit on out-of-core surfaces. One of the main objective of the Coolant Chemistry is to help to decrease the radiation exposures. For this purpose, coolant chemistry was improved stepwise to decrease the source term of the PWR radiation fields since decades based on the gained field experience.

The primary source of PWR radiation fields in older plants is Cobalt-60, formed by a (n, γ)-reaction from Cobalt-59 (elemental Cobalt). Cobalt-58 is formed by the Ni-58 (n,p)-reaction with fast neutrons and it is the second most important contributor to out-of-core radiation fields in older PWRs. However, in newer plants, where the major sources of Cobalt are removed, e.g. where the Cobalt-60 problem is minimised, the Cobalt-58 becomes the most important issue.

In order to minimise the contribution of these radio-nuclides to out-of-core radiation fields, the sources of elemental cobalt and Nickel have to be identified and it has to be discussed how their contribution to radiation exposure can be controlled by coolant chemistry programs. The major source for elemental Cobalt (and thereby Cobalt-60) is the corrosion and wear of Cobalt base alloys (e.g. Stellites) and the Cobalt impurities in RCS structural materials (e.g. SG tubing). The major source for Nickel is the Steam Generator Tubing material.

In this presentation, each of the important factors for PWR radiation field reduction will be discussed in detail including and emphasising the plant experience gained in this field.

"I find the Seminars very useful, not only for the presentations but also to meet the speakers and other colleagues for some fruitful discussions"

BERNT BENGTSSON
Vattenfall, Sweden

Invited Presentations

- Decommissioning Preparation at Mühleberg. Chemistry transition by ***Christoph Weber***
- Another presentation to be defined later

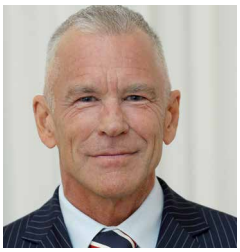
LCC14 Experts

The experts are: Dr. Francis Nordmann, formerly at Électricité de France, Mr. Peter Rudling, president of ANT International, Dr. Samson Hettiarachchi, formerly at GE Hitachi, Dr. Suat Odar, formerly at AREVA, Mr. Dewey Rochester, formerly at Duke Energy, Mr. François Cattant, formerly at Électricité de France.

Dr. Francis Nordmann has over 48 years of experience in power plant chemistry. He is retired from Électricité de France (the French Utility) in 2007, where he was an international expert in charge of chemistry and corrosion in the corporate offices. He was in charge of managing the engineering studies for the French fleet of 58 PWR units and of several international programmes. His Ph. D degree was obtained at the French Atomic Energy Commission, in connection with the University of Mulhouse in 1973. He also worked for 8 years within the French manufacturer Framatome.

He has been active for example in the following areas:

- Water Chemistry evolution and studies for the various systems (primary coolant, secondary steam-water system, condenser cooling systems, and intermediate circuits)
- Developing the Chemistry Specifications for the French NPP and some others
- Interface with Manufacturers and Regulatory Body
- Chemistry and corrosion training
- Steam Generator blowdown and condensate polishers strategy
- Optimisation of secondary water chemistry for various objectives
- Steam Generator experience feedback and relation with chemistry
- Tutorial sessions and workshops for various organisms (France, IAEA)
- International projects with various countries and organisations: IAEA, USA, EPRI, Japan, South Africa, China, Germany, Sweden, Spain, Russia, Ukraine, Bulgaria, Hungary, etc.
- Organising committee of several International Conferences on Chemistry for Nuclear Reactors. He was Chairman of this Conference in Avignon, France.



Mr. Peter Rudling is the President of ANT International, managing the ZIRAT/IZNA/LCC Programmes as well as providing seminars and Handbooks on various fuel related topics to the nuclear industry. Peter was a senior consulting scientist at Vattenfall, the largest Swe-dish power company. Earlier he has also been a Specialist of Fuel Materials at ABB Atom (now Westinghouse) and a Project Manager at EPRI.

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 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 has participated 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. Suat Odar has 48 years of experience in power plant chemistry. He retired from AREVA NP GmbH (Former Siemens and KWU) in February 2008, where he has held since mid of eighties various service and managerial positions for power plant chemistry. In the last seven years he was responsible for the water chemistry of the nuclear power plants in his company. His degree as Ph.D. in Physical Inorganic Chemistry was obtained from the Technical University of Darmstadt, Germany, in 1970.
He has been active for example in the following areas:

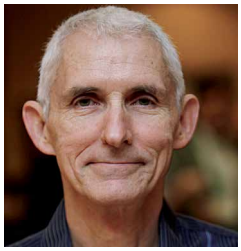
- Water Radiolysis and Post LOCA Hydrogen Control in PWR Containment
- Commissioning of PWR plants
- Developing Chemistry Control concepts for PWRs
- Water Chemistry Guidelines
- Consulting in Power Plant Operation (Chemistry part)
- Improvement of Steam Generator Performance
- Man-Rem-Reduction
- Plant Life Extension (Chemistry measures)
- Steam Generator Chemical Cleaning
- Plant Chemistry Training Programs
- Secondary Side System Design & Material Review to improve Steam Generator Performance

Mr. Dewey Rochester retired from Duke Energy Carolinas LLC in June 2010 after working for thirty six years in the field of nuclear power plant chemistry. He began his career in May 1974 at Duke's Oconee Nuclear Station as a Junior Chemist. He was promoted to site Chemistry Manager in February 1978. In September 1984 he transferred to the corporate office to lead the process qualification programme for the steam generator chemical cleaning at Oconee.

From 1989 until 2003 he worked on a variety of projects dealing with primary and secondary water chemistry, and steam generator corrosion issues as well as performing assessments of plant chemistry performance. In February 2003 he was promoted to Duke Energy's Corporate Nuclear Chemistry Manager, where he led the group responsible for the development of the site chemistry programmes at Duke's three nuclear sites. During his career he has worked in all phases of nuclear power plant chemistry including makeup water production, primary and secondary chemistry, radwaste processing and steam generator chemical cleaning and corrosion. He has authored and co-authored several papers on steam generator chemical cleaning, radwaste processing, steam generator corrosion issues, and the use of dispersants to mitigate steam generator deposition. He also made numerous presentations at various conferences and seminars.
Some of his interests include:

- Chemical cleaning processes and corrosion monitoring
- Core design impact on corrosion product releases
- The use of dispersants for steam generator deposition mitigation
- Post-accident sampling systems
- Steam generator corrosion issues
- Primary and secondary water chemistry guidelines
- Zinc addition to mitigate plant dose rates

He served twice as Chairman of the Babcock & Wilcox Steam Generators Owner's Group, Chairman of the EPRI Chemistry Subcommittee and a member EPRI Steam Generator Owner's Group Technical Support Subcommittee and Integration Committee.



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:

- 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.
During this period:

- he was under contract with EPRI, being EPRI technical expert regarding several destructive examinations such as North Anna 2 RPV head penetrations, South Texas Project 1 Bottom Mounted Instrumentation, Braidwood 1 pressurizer heater #52, San Onofre 3 CEDM #64...
- he was the President of the "Materials, Non Destructive Testing and Chemistry" section of the "French Nuclear Energy Society" (from 2004 to 2008);
- he was also the Materials Ageing Institute (MAI) International Partnership Manager.

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.

Price and Terms of Payment

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

Terms and Conditions

The term of LCC14 Programme starts from the date of the purchase order and lasts 12 months onwards.

A.N.T. 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 A.N.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.

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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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