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REPORT LIST

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AUGUST 2024

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THE OBJECTIVE OF the handbooks and reports on current issues is to provide guidance for those needing to get an introduction to and an initial understanding of the topics covered or to update and refresh the memory of those with materials/plant chemistry background. This group includes individuals ranging from young engineers, researchers, specialists to upper management. The handbooks and reports are written and explained in such a way that those not familiar with the topic can follow the report, and find and grasp the appropriate information. This means that the reports can be used by the organisation in the training of the internal staff with or without additional assistance from the A.N.T. International staff. The handbooks and reports are offered to nuclear utilities, fuel vendors, research laboratorie and regulatory agencies.

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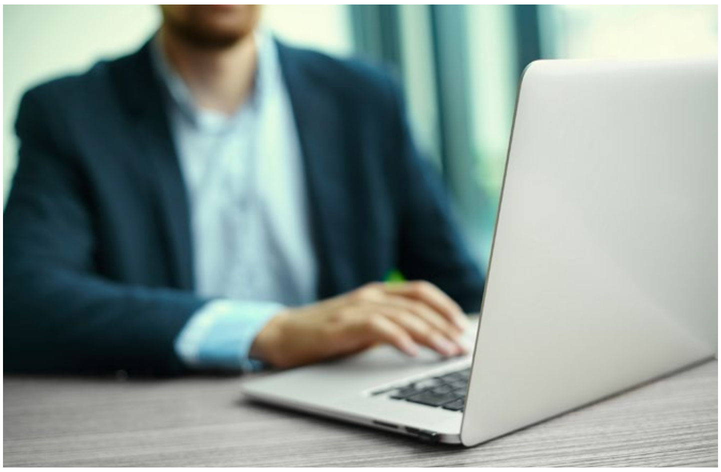


A.N.T. INTERNATIONAL® **REPORT LIST**

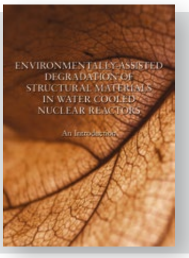
Previously published

LCC REPORTS

LWR Chemistry and Component Integrity Programme

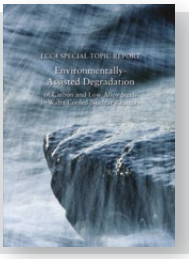
Read more about the LCC Programme: www.antinternational.com/lcc

STAND ALONE REPORTS LCC



Environmentally-Assisted Degradation of Structural Materials in Water Cooled Nuclear Reactors – An Introduction (SMDR)

The first Report in this series covers all different degradation modes of stainless steels and nickel base alloys.

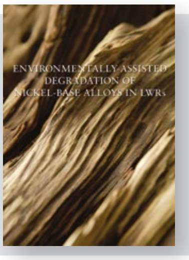


Environmentally-Assisted Degradation of Carbon and Low-Alloy Steels in Water Cooled Nuclear Reactors (LCC4 STR)

The second Report in this series focuses on the degradation of carbon and low alloy steels.

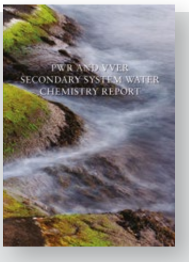
Environmentally-Assisted Degradation of Stainless Steels in LWRs (EADS)

The third Report in this series covers degradation of austenitic stainless steels.



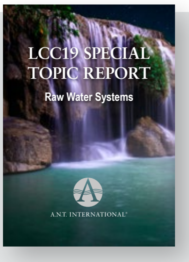
Environmentally-Assisted Degradation of Nickel-Base Alloys in LWRs (EADN)

The fourth Report in this series is related to degradation of nickel-base alloys in LWR primary coolant systems.



PWR and VVER Secondary System Water Chemistry (SSWC)

Adequate secondary side water chemistry is crucial for safe and economical PWR and VVER plant operation. A good practised water chemistry control avoids degradation problems of the key components, such as steam generators (SG), carbon steel components and turbine. This Report gives a complete overview of the various rationale approaches to optimise the water chemistry according to the design and materials as well as the specific situation of each Nuclear Power Plant.

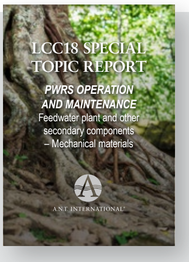


PWRs Operation and Maintenance Raw Water Systems (LCC19)

Raw water has a major safety role as acting as cold source for plants. Raw water is used for:

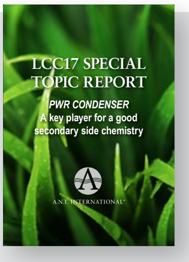
- Cooling the condenser, either in open or in closed circuits
- Providing water for service water systems
- Providing water to the Fire Fighting System
- Providing water to the Auxiliary Feedwater Tank in case of emergency (earlier units)

The report covers the following topics: design consideration, raw water chemical treatments, operating experience along with the maintenance programmes of raw water systems.



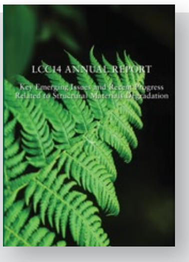
PWRs Operation and Maintenance– Feedwater Plant and Other Secondary Components – Mechanical Components (LCC18)

This report compiles field operating experience and maintenance of some of the following PWRs components: heaters and reheaters, pumps, valves, piping and their supports, heat exchangers and bolted connections.



The condenser: a key player for a good feedwater chemistry (LCC17)

This report compiles the degradations observed in condensers, either on steam side or raw water side. The oldest condensers were known before the nuclear era, the newest came to the light with the development of nuclear reactors. However, more attention was brought to nuclear plant condensers since while operating with a few leaks was allowed in fossil fired plants, this was strictly forbidden in pressurized water reactors, mainly because of the steam generators susceptibility to pollution.

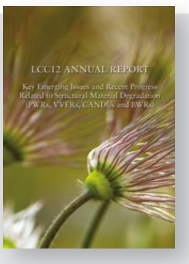


Key Emerging Issues and Recent Progress Related to Structural Materials Degradation (LCC14 AR)

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.

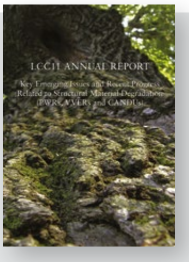
EPRI LWRs Material Reliability 2016 Conference (LCC13 AR)

For many years, EPRI has organised conferences on light water reactors materials reliability. Given there was neither Environmental Degradation nor Fontevraud conferences in 2016, EPRI took the opportunity of providing this conference in 2016. During days 2 to 4, 104 slides were presented in 3 parallel sessions, which covered 18 topics on a whole range of concerns of LWRs.



Key Emerging Issues and Recent Progress Related to Structural Material Degradation, 2015 (LCC12 AR)

This Report discusses the PWR/VVER/CANDU/BWR highlights from the 17th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, that was held in Ottawa, Canada in 2015.

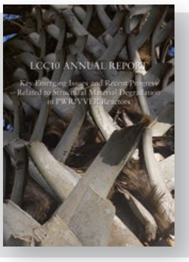


Key Emerging Issues and Recent Progress Related to Structural Material Degradation in PWRs, VVERs and CANDUs 2014–2015 (LCC11 AR)

This Report reviews the key information presented at the “Fontevraud International conference” which was held in Avignon, France, in September 2014. In this conference, research work, related to field failures and issues of various reactor components, is also presented. This Report reviews the papers relevant to PWRs, some BWRs, VVERs and CANDU reactors.

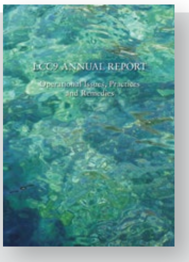
Key Emerging Issues and Recent Progress Related to Structural Material Degradation (BWRs and some PWRs) 2013–2014 (LCC11 AR)

This Report discusses the PWR/VVER highlights from the 16th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, that was held in Ashville, NC in August 2013.



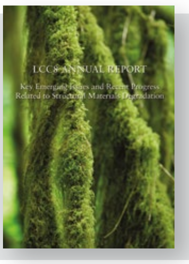
Key Emerging Issues and Recent Progress Related to Structural Material Degradation, 2013–2014 (LCC10 AR)

This Report discusses the PWR/VVER highlights from the 16th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, that was held in Ashville, NC in August 2013.



Operational Issues, Practices and Remedies (LCC9 AR)

This Report combines the following subjects of limited extent but potentially important consequences: Degradation of the primary coolant barrier together with mechanical remedies, The potential benefits of Enriched Boric Acid (EBA), Primary coolant (Co-58, colloids) inventory, Degradation of concrete structures in NPPs, Colloids, Zeta Potential and Activity Transport, Electrochemical Corrosion Potential (ECP) measurements and Key points, ”lessons learned” and ”best practices” of several recent conferences.



Key Emerging Issues and Recent Progress Related to Structural Material Degradation (LCC8 AR)

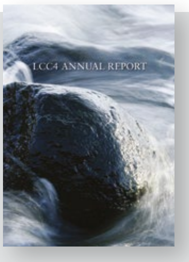
This Report discusses the highlights from the 15th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, which was held in Colorado Springs in August 2011.

Key Results From Recent Conferences on Structural Materials Degradation in Water Cooled Reactors (LCC6 SR)

This Report reviews the key papers published in the following conferences: The 14th International Conference on “Environmental Degradation of Materials in Nuclear Power Systems”, Virginia Beach, USA, August 24–28, 2009. The Fontevraud 7 Conference “Contribution of Materials Investigations to Improve the Safety and Performance of LWRs”, Avignon, France, September 26–30, 2010. Jubilee day seminar on “Stress Corrosion Cracking of Nickel Base Alloys at CEA – Coriou Effect”, Saclay, France.

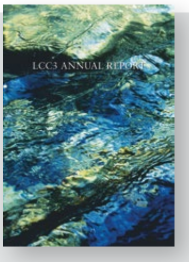
Annual Report Covering Results Published During 2008–2009 (LCC5 AR)

The Report covers the following topics:
1. PWR/VVER primary side coolant chemistry.
2. BWR coolant chemistry.
3. PWR and VVER secondary side chemistry.
4. Materials degradation.
5. Intergranular stress corrosion cracking and irradiation-assisted stress corrosion cracking of cold worked/irradiated stainless steels in de-oxygenated PWR-type coolants.



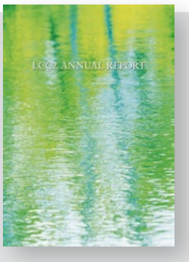
Annual Report Covering Results Published During 2007–2008 (LCC4 AR)

The Report covers the following topics:
1. Nuclear plant primary water chemistry experience (PWR, VVER and BWR).
2. Water chemistry sampling and monitoring (PWR, VVER and BWR).
3. Corrosion product control and sampling technique (secondary side, PWR, VVER).
4. Material degradation management.
5. Fuel /water chemistry interaction.
6. Behaviour of radiolysis gases in BWRs and PWRs.



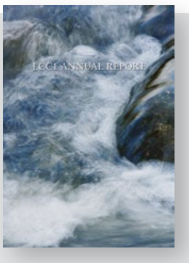
Annual Report Covering Results Published During 2006–2007 (LCC3 AR)

The Report covers the following topics:
1. Secondary side steam generator tube problems.
2. Structural Materials Degradation.
3. Electrochemical membrane methods in LWR cleanup systems.
4. Effect of water chemistry on fuel cladding.



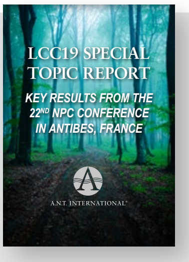
Annual Report Covering Results Published During 2005–2006 (LCC2 AR)

The Report covers the following topics:
1. Coolant Quality and Control Issues – PWR/VVER Water Chemistry – BWR water chemistry.
2. Structural Materials Degradation.
3. Primary Circuit Corrosion (BWRs and PWRs) – SCC, PWSCC in PWRs – SCC in BWRs and remedies (HWC, NMCA).
4. Dose Rate Buildup and Control (BWRs and PWRs).



Annual Report Covering Results Published During 2004–2005 (LCC1 AR)

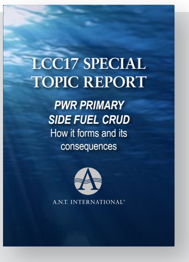
The Report covers the following topics and more:
1. Coolant Quality and Control Issues – PWR Water Chemistry – BWR water chemistry.
2. Materials selection for the primary BWR and PWR circuits.
3. Dose Rate Buildup and Control.
4. Fuel/Water Chemistry Interaction.



Key Emerging Issues and Recent Progress Related to Plant Chemistry/ Corrosion (PWR, CANDU, and BWR Nuclear Power Plants) (LCC19)

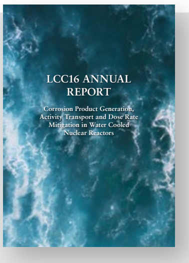
Safety and reliability of power plants are becoming increasingly important factors since many plants are aging and have obtained license renewal for continued power operation and also for new reactors using different technologies that are or will be in design, construction, commissioning, or start-up stage. Therefore, sharing plant operating experiences, sharing lessons learned, and sharing new industry research are all crucial in order to maintain the nuclear power plant fleet in a healthy condition as well as for new reactors using different technologies that are or will be in design, construction, commissioning or start-up stages.

This report on Key Emerging Issues and Recent Progress, ANT International has collected the most relevant experiences and advanced research exposed at the Nuclear Plant Chemistry Conference NPC-2023 that took place in Antibes Juan-les Pins, France in September.



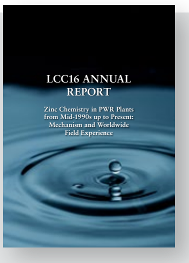
Deposit Formation on Fuel Cladding in PWR Primary Systems (LCC17AR)

Formation of deposits on Pressurised Water Reactor (PWR) fuel cladding has been an inherent problem in these systems since their inception and remains a problem to-date. The report provides: 1) a brief history of fuel crud in PWR systems, 2) mechanisms for material release, transport and deposition in the core and the influence by material choice, coolant chemistry and core design 3) discussions of what occurs within fuel crud that may affect its deposition rate, its effect on core neutronics and possible impact on clad corrosion leading to failure. Finally, a discussion is given summarizing our current understanding and where future work is required to further this knowledge.



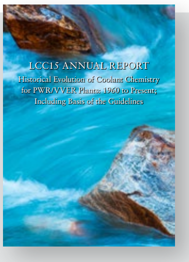
Corrosion Product Generation, Activity Transport and Dose Rate Mitigation in Water Cooled Nuclear Reactors (LCC16 AR)

This report discusses in detail, the steps involved in, generation of corrosion products including colloid formation, activation on fuel, transport through the coolant, deposition on surfaces including zeta potential effects, release from surfaces and removal of activated corrosion products in light water reactors. The report also discusses activity transport that will include basic steps involved and models used.



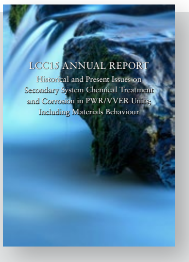
Zinc Chemistry in PWR Plants from Mid-1990s up to Present: Mechanism and Worldwide Field Experience (LCC16 AR)

This updated report reviews, as of 2020, the laboratory and field results of zinc injection technology in PWR plants worldwide. The review covers the range from basic information to current knowledge and understanding of operational behaviour. This information on PWR plants given in this report is also applicable for VVER plants.



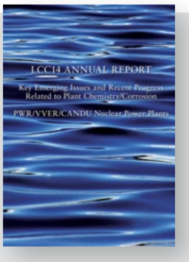
Historical Evolution of Coolant Chemistry for PWR and VVER Plants: 1960 to present; Including Basis of the Guidelines (LCC15 AR)

This report describes the historical development of the water chemistry in primary side of the PWR and VVER plants since 1950s up to present. It covers many aspects including material degradations, their mitigation, guidelines explanation and recommendations on coolant chemistry strategies.



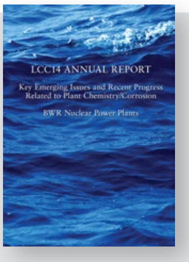
Historical and Present Issues on Secondary System Chemical Teatment and Corrosion in PWR/VVER Units; Including Materials Behaviour (LCC15 AR)

This report describes the past and present issues related to secondary system chemistry and materials behaviour. It covers many aspects including material evolution and chemistry selection, guidelines explanation, behaviour of added reagents and of impurities, integrity and long-term behaviour of the plant.



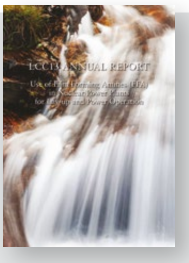
Key Issues in Plant Chemistry and Corrosion – PWR, VVER, CANDU – 2018 (LCC14 AR)

This first report on PWRs, VVERs, CANDUs and PHWRs summarises and analyses the results to assess in which specific situation the results are applicable and gives the point of view of A.N.T. International expert. Instead of giving a short summary of each paper presented at the conference, the report covers the key facts, either new or of significant interest for LCC customers.



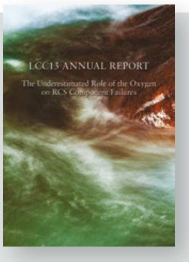
Key Issues in Plant Chemistry and Corrosion in BWRs – 2018 (LCC14 AR)

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.



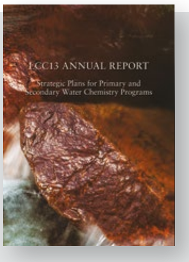
Use of Film Forming Amines (FFA) in Nuclear Power Plants for Lay-Up and Power Operation (LCC13 AR)

This report presents a new corrosion inhibitor based on film forming amines (FFA), which are often referred to as fatty amines or polyamines. FFA can form a mono-molecular hydrophobic film or layer adsorbed on the metal surfaces, that constitutes a homogeneous protective barrier against corrosion by its water-repellent behaviour.



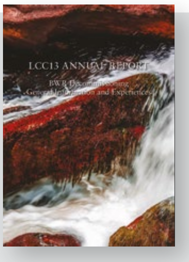
The Underestimated Role of The Oxygenon RCS Component Failures (LCC13 AR)

PWR chemists may claim that there is no oxygen in the Reactor Cooling System because hydrogen injection suppresses the oxidising species generated by radiolysis. This is why, at EDF, the RCS has no oxygen monitoring. In fact, this assessment is true only if free flowing conditions are considered. The RCS contains many flow-restricted or occluded zones where some chemistry deviations can occur, one being the presence of oxygen.



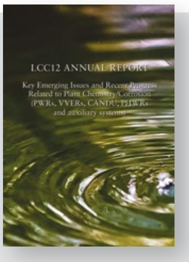
Strategic Plans for Primary and Secondary Water Chemistry Programmes (LCC13 AR)

This document explains the Objective and Optimisation Methodology of this Strategic Water Chemistry Plan. For the Primary Coolant, it includes the Parameters Impacting or not the Pressure Boundary or Fuel Cladding Integrity. For the Secondary System, it includes the key elements and the components susceptibility and reliability. The report is of benefit to those non-U.S. utilities in developing their own water chemistry programs, both primary and secondary side.



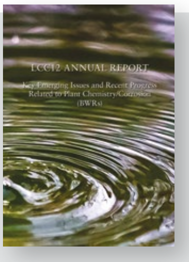
BWR Decommissioning General Information and Experiences (LCC13 AR)

During decommissioning, plant sites typically use one of three approaches, Immediate Dismantling (DCON), Safe Enclosure (SAFSTOR) or Entombment (ENTOMB). Each approach has its benefits and disadvantages although most plants have used the SAF-STOR approach.



Key Emerging Issues And Recent Progress Related to Plant Chemistry/Corrosion in PWR/VVER/CANDU, PHWR, and Auxiliary Systems) 2016 (LCC12 AR)

This Report cover the key information in PWR/VVER/CANDU Reactors presented at the 20th Nuclear Power Chemistry Conference, in October 2016. The Report not only summarises but also analyse the results to assess in which specific situation the results are applicable.



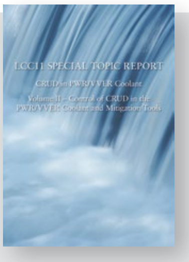
Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion in BWR Reactors, 2016 (LCC12 AR)

This Report cover the key information presented at the 20th Nuclear Power Chemistry Conference, in October 2016. The Report not only summarises but also analyse the results to assess in which specific situation the results are applicable.

Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion in PWR/VVER/CANDU Reactors 2014–2015 (LCC11 AR)

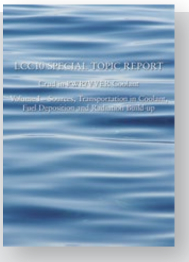
This Report is covering two technical aspects dealing with:

1. Recycling of waste in primary coolant and,
2. Secondary water chemistry options and Hide out return of impurities from Steam Generators.



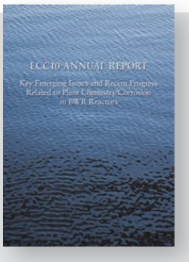
CRUD in PWR/VVER Coolant — Volume II: Control of CRUD in The PWR/VVER Coolant and Mitigation Tools (LCC11 STR)

The purpose of the Volume II of this Report is to describe the tools and their application to adequately control the coolant crud in order to improve the fuel and out-core radiation performance. Secondary water chemistry options and Hide out return of impurities from Steam Generators.



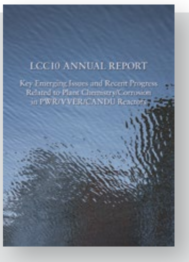
CRUD in PWR/VVER Coolant — Volume I: Sources, Transportation in Coolant, Fuel Deposition and Radiation Build-up (LCC10 STR)

The topic is covered in two separate volumes. This document, Volume I, covers the following topics: Sources of CRUD, CRUD Transportation in PWR/VVER Coolant, CRUD Deposition in the Core CRUD Release from Core and Radiation Build-up Mechanism.



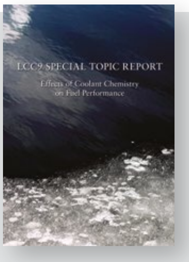
Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion in BWR Reactors (LCC10 AR)

This Report cover the key information presented at the Nuclear Power Chemistry Conference, in October 2014. The Report not only summarises but also analyse the results to assess in which specific situation the results are applicable.



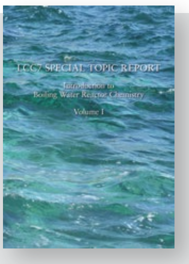
Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion in PWR/VVER/CANDU Reactors (LCC10 AR)

This report is related to PWR, VVER CANDU, HPWR reactors as well as some of the various other topics more or less independent from the type of reactors, such as maintenance, fuel, future trends, auxiliary systems, wastes, etc. The Report not only summarises but also analyse the results to assess in which specific situation the results are applicable.



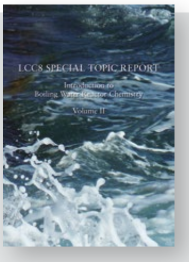
Effects of Coolant Chemistry on Fuel Performance (LCC9 STR)

The intent of this Report is to provide a state-of-the-art knowledge of the mechanisms of the various forms of Zr-alloy corrosion and hydrogen pickup (HPU) and how water chemistry impacts fuel performance, including corrosion and HPU. This knowledge will help implement actions to reduce Zr alloy corrosion and hydrogen pickup.



Introduction to Boiling Water Reactor Chemistry — Volume I (LCC7 STR)

This Report is the first volume out of two focusing on BWR chemistry. The Report includes the basics of water radiolysis, the dynamic process that establishes the concentration of oxygen and hydrogen gas in the reactor water, the consequences of tramp uranium and leaking fuel rods on chemistry and other relevant topics. which specific situation the results are applicable.



Introduction to Boiling Water Reactor Chemistry — Volume II (LCC8 STR)

This Report is the second volume out of two focusing on BWR chemistry. This volume II takes a closer look at corrosion of structural materials covering the following topics: Corrosion Considerations, Stress Corrosion Cracking Mitigation, Start-up IGSCC Mitigation, Shutdown Dose Rate Minimization, Reactor Water Purity Transients, Surveillance Programs.

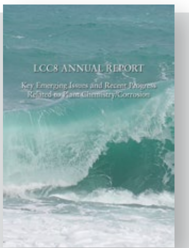
PWR/VVER Primary Side Coolant Chemistry — Volume II: Water Chemistry Tool to Mitigate the Concerns (LCC8 STR)

The second volume out of two focusing on PWR/VVER chemistry and covers the following topics:

1. Chronology of Coolant Chemistry. / Current Coolant Chemistry Programs.
2. Coolant Chemistry Guidelines & Practices.
3. Purification and Filtration of the Coolant Monitoring Concept.

PWR/VVER Primary Side Coolant Chemistry — Volume I: Technical Basis and Recent Discussions (LCC7 STR)

The first volume out of two focusing on PWR/VVER chemistry. This document is intended to provide a detailed description of the PWR/VVER Primary Side Coolant Chemistry. Furthermore, it should provide a strong support to the utilities for establishing a responsive plant specific chemistry program. It may also help the Manufacturers and Regulators at having a detailed approach of primary water chemistry and corresponding issues.



Key Emerging Issues and Recent Progress Related to Plant Chemistry/Corrosion (LCC8 AR)

This Report contains plant chemistry, corrosion issues and their recent progress from the following three conferences held in the year 2012:

1. The EPRI Steam Generator Secondary Side Management Conference.
2. BWR issues presented in the EPRI Conference.
3. The Nuclear Power Chemistry Conference.

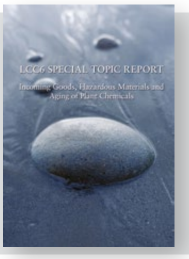
Operational Issues and Practices in PWRs (LCC7 STR)

This Report combines topics of potentially important consequences:

1. Total Organic Carbon (TOC) in primary and secondary system water.
2. Best practices for corrosion products removal in reactor coolant systems (RCS) of VVERs and the use of mechanical filters or macro-porous resins.
3. Best practices for the use of Ion Exchange Resins for RCS, SG blowdown, and the spent fuel pool.
4. Best practices to mitigate condenser leakages and recommendations for Operation procedures in case of large impurities ingress.
5. The Use of Dispersant to Mitigate Steam Generator Corrosion Product Deposition.

Effect of Zinc in BWR and PWR/VVER on Activity Build-Up, IGSCC and Fuel Performance (LCC6 STR)

This Report gives a comprehensive understanding of the zinc chemistry mechanism and information on how Zinc Chemistry in BWR and PWR plants was introduced in the plants and explains the results achieved.



Incoming Goods, Hazardous Materials and Aging of Plant Chemicals (LCC6 STR)

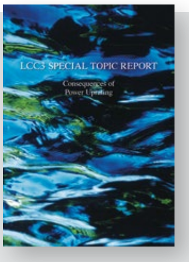
The objective of this Report is to provide a comprehensive understanding of controlling the quality.

Radiochemistry in Nuclear Power Reactors (Light Water Reactors) — Volume I (LCC6 STR)

The objective of this Report is to provide a comprehensive understanding of radiochemistry in Nuclear Power Plants which has a large impact on dose rates, operational exposures, maintenance activities, shutdown process, safety issues, environmental constraints and control of proper plant operation.

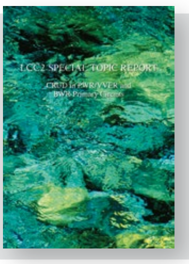
Circuits of PWRs, VVERs and CANDUs (LCC5 STR)

The Report provides a worldwide review of Startup and Shutdown Procedures both in the Primary and in the Secondary Circuit of PWRs, CANDUs and VVERs, and in the reactor coolant and main steam containing systems of BWRs.



Consequences of Power Uprating (LCC3 STR)

A relatively high percentage of all operating LWRs in the world have implemented or are considering some kind of increase of the power (power uprate). This Report provides a worldwide review of power uprates. Water chemistry and radiology experiences of power uprates are presented separated on BWRs and PWRs. Key issues are identified and discussed and available options to assure maintained or improved conditions at power uprates are presented.



CRUD in PWR/VVER and BWR Primary Circuits (LCC2 STR)

The objective of this Report is to provide members with the basic understanding of the mechanisms involved and their relationship to material performance and activity buildup.

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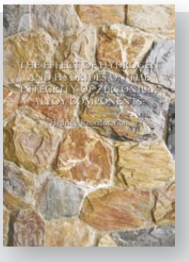


The Effect of Hydrogen and Hydrides on the Integrity of Zirconium Alloy Components: Hydride Reorientation

Hydride orientation has an important effect on fracture toughness of hydride-containing zirconium alloys because hydrides form as approximately linear arrays of platelet-shaped microscopic precipitates with habits on or near the basal planes of the α–Zr matrix in which they form.

Fuel Design Review Handbook (FDRH)

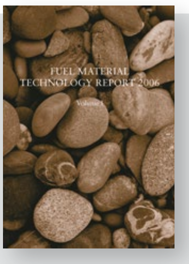
This handbook intends to provide a guide to the items that have the greatest influence on fuel performance and prioritise the audits that are recommended.

Management of BWR Control Rods (MBCR)

The objective of this Report is to provide the customers with information which will be a useful tool for management of control rods.

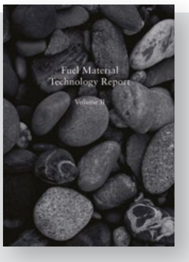
Fuel Fabrication Process Handbook (FFPH)

The objective of the Fuel Fabrication Process Handbook is to provide guidance for a cost effective audit which uses audit time on areas which are most likely to affect the performance of the PWR/ VVER and BWR fuel. The FFPH focuses on a “Process Audit” procedure, the audit of the fabrication process parameters for making high quality fuel.



Fuel Material Technology Report (FMTR) — Vol. I

This first volume covers short general outlines of the designs of PWR, BWR, CANDU, VVER and RBMK reactors but with focus on the corresponding fuel assembly and supporting structure designs together with the rational for the selection of the materials used in the different applications. This volume also gives an overview of the in-reactor fuel performance, of fuel performance codes and the manufacturing process of the fuel assembly.



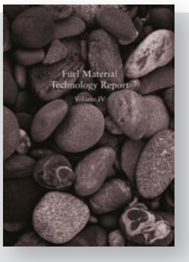
Fuel Material Technology Report (FMTR) — Vol. II

In this second volume, the following topics for different water cooled type reactors are covered:

1. Effect of radiation on the various fuel assembly materials as well as the interaction between materials and cooling water chemistry in this radioactive environment.
2. Water chemistries in different reactor types.
3. Fuel design criteria and operating limits
4. Fuel performance during Loss Of Coolant Accidents and Reactivity Initiated Accidents.
5. Fuel performance during intermediate storage.
6. Trends and potential burnup limitations.

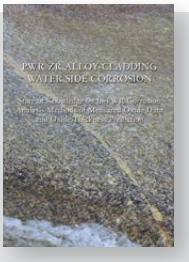
Control Assembly Technology Report (FMTR) — Vol. III

The Report constitutes Volume III of the series of Fuel Material Technology Reports. It describes the designs, manufacturing, performance and issues related to BWR/PWR/VVER/CANDU Control Assemblies with Ag-In-Cd (AIC), B4C, Hf absorber materials and stainless steel structural materials.



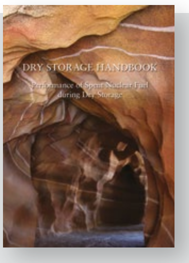
Fuel Material Technology Report (FMTR) — Vol. IV

The primary objective of this volume is to provide guidance in improving fuel reliability. To reach this objective, various Poolside and Hot Cell Examinations techniques may be used. A good knowledge of the pros- and cons- of the different techniques can guide the utility or fuel vendor to select the most cost efficient techniques for their specific goals. A second objective of this Report is to document this knowledge in a form which can be updated as new information, and methods become available.



PWR Zr Alloy Cladding Water Side Corrosion (PZAC)

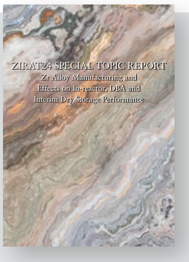
The Report discusses the different parameters impacting PWR fuel corrosion and provides a computer code which allows an equivalent comparison of new alloys irradiated in different reactors at different conditions. The computer code may also assist in identifying the mechanism why the corrosion rate starts to accelerate under certain conditions.



Dry Storage Handbook — Fuel Performance in Dry Storage

This handbook contain a technical assessment of the expected performance of spent nuclear fuel (SNF) during extended dry-storage time periods and the condition of such fuel at the end of dry storage. The principal focus of the reviews is on SNF and the effects of dry storage rather than on dry-storage containers and the related storage facilities. The objective is to provide background information on the likely behaviour of materials comprising water reactor fuel assemblies and on the performance of integral assemblies under conditions typical of dry storage for extended intervals of time.

Manufacturing of Zr Alloys



Zr Alloy Manufacturing and Effects On In-reactor, DBA and Interim Dry Storage Performance (ZIRAT24/IZNA19 STR)

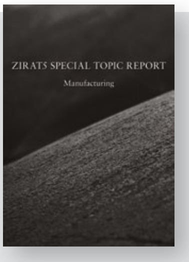
The overall objective of this Special Topic Report (STR) is to provide the knowledge of how the reactor environment (fast neutron flux, temperature, water chemistry, etc.) and the Zr-alloy microstructure, which is a function of material chemistry and manufacturing process, impacts fuel performance during normal operations, transients, design basis accidents and interim dry storage

Impact of Manufacturing Changes on Zr Alloy In-pile Performance (ZIRAT14/IZNA9 STR)

This Report provides an overview of Zr alloy manufacturing process and relationship between fabrication, microstructure and in-pile performance.

Manufacturing of Zr-Nb Alloys (ZIRAT11/IZNA6 STR)

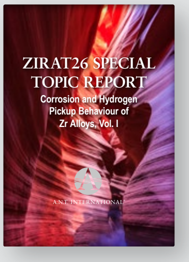
The Report covers the impact of manufacturing on microstructure and in-reactor performance of Zr-Nb alloys. The Report was co-authored by Russian scientists involved in the development of the Russian Alloys E110, E635 and E125.



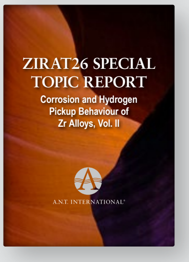
Manufacturing of Zirconium Alloy Material (ZIRAT5 STR)

This special topical Report on zirconium alloy manufacturing and impact on in-pile fuel performance has been prepared within the ZIRAT5 Programme. The objective of this Report is to provide members with the basic understanding of the mechanisms involved and their relationship to fuel performance.

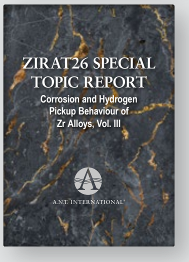
Corrosion and Hydrogen pickup (HPU) mechanisms of Zr alloys remain a top priority of the nuclear industry. Commercial Zr alloys have today adequate in-reactor corrosion properties. However, hydrogen in fuel components limits the fuel performance today during normal operation and accident conditions as well as during transport of spent fuel. Despite more than 50 years research, the corrosion and HPU mechanisms are still not clear. Improved understanding of the in -reactor oxidation and hydrogen pickup mechanisms are thus required. To shed light on theses complicated mechanisms A.N.T. International has published a set of three reports (Vol. I, II and III) with the focus on explaining the very complicated corrosion and hydrogen pickup mechanisms in an understandable manner.



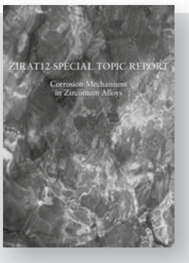
Volume I gives an introduction on the corrosion and hydrogen pickup (HPU) processes in zirconium alloys. The following topics are treated in details:
· The effects of in-reactor irradiation on both zirconium alloys and the coolant (radiolysis)
· Crud sources, transport mechanisms and deposition mechanisms
· Axial offset anomalies
· Reactor cases of severe crud impact on fuel performance



Volume II gives more detailed information on:
· Early Zr alloy development
· Out-of-reactor corrosion
· General in Reactor Corrosion and Hydrogen Pickup behaviour
· Effects of alloying impurities on corrosion and HPU
· Corrosion modelling and prediction



Volume III gives an introduction to the best understood mechanisms of Zr alloys corrosion and HPU mechanisms, with the aim of giving a ”mental image of the phenomena”, more than discussing in detail all the controversial aspects of the current scientific debates.

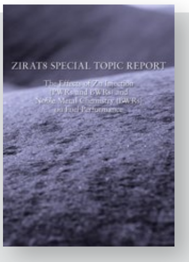


Corrosion Mechanisms in Zirconium Alloys (ZIRAT12/IZNA7 STR)

The intent of this Report is to discuss the corrosion mechanisms and the various forms of corrosion features (uniform, nodular and shadow corrosion) in BWRs and PWRs/VVERs. This knowledge will give the possibility to implement actions to reduce corrosion.

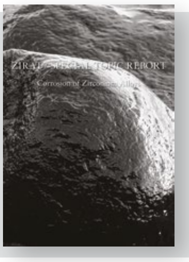
Corrosion of Zr-Nb Alloys in PWRs (ZIRAT9/IZNA4 STR)

The Report gives an overview of the development of the Zr-Nb alloys in the nuclear industry, as well as the basic metallurgy and manufacturing of the Zr-Nb alloys. The Report focuses on the out-ofreactor as well as in-reactor corrosion and hydrogen pickup performance.



The Effects of Zn Injection (PWRs and BWRs) and Noble Metal Chemistry (BWRs) on Fuel Performance (ZIRAT8/IZNA3 STR)

This Report reviews the experience of the impact of Zn-injection (in PWRs and BWRs) and Nobel Metal Chemical Addition (NMCA) in BWRs on fuel integrity. The Report also discusses fundamentals in crud formation related to Zn-injection and NMCA.



Corrosion of Zirconium Alloys (ZIRAT7/IZNA2 STR)

This Report covers all aspects of Zirconium alloy corrosion and hydrogen pickup out-of-reactor as well as in-reactor.

Water Chemistry and CRUD Influence on Cladding Corrosion (ZIRAT6/IZNA1 STR)

The purpose of the Report is to describe the fundamentals in crud formation, transport, and deposition, in order to provide a solid basis for evaluating and analysing any fuel operational problem due to crud deposits.

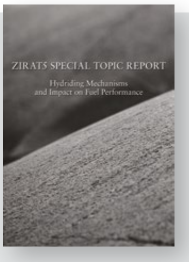
Properties of hydrides and impact on fuel in-reactor performance

Effect of Hydrogen on Zirconium Alloy Properties – Vol I (ZIRAT13/IZNA8 STR)

The intent of these two Reports is to discuss the basics of hydrogen, hydrides and their effect on the zirconium alloy properties in Volume I and in-pile performance during normal and accident conditions as well as dry storage in Volume II.

Effect of Hydrogen on Zirconium Alloy Performance (Normal Operation, LOCA/RIA and Dry Storage) – Vol II (ZIRAT13/IZNA8 STR)

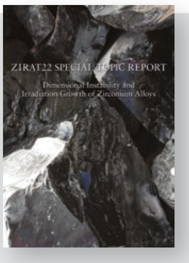
The intent of these two Reports is to discuss the basics of hydrogen, hydrides and their effect on the zirconium alloy properties in Volume I and in-pile performance during normal and accident conditions as well as dry storage in Volume II.



Hydriding Mechanisms and Impact on Fuel Performance (ZIRAT5/IZNA1 STR)

The objective of this Report is to provide the basic understanding of the hydrogen pickup and redistribution mechanisms involved and the impact of hydriding on fuel performance.

Dimensional changes of fuel assemblies/channels and components



Dimensional Instability and Irradiation Growth of Zirconium Alloys (ZIRAT22/IZNA17 STR)

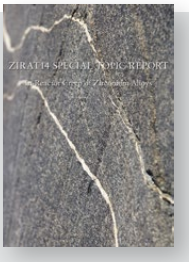
In this STR review, aimed specifically at irradiation growth, addressed are conditions of direct interest to LWRs and CANDUs, including information that has mechanistic implications. Irradiation creep was covered earlier by ZIRAT14 Special Topic Report: In-reactor Creep of Zirconium Alloys, authored by Ron Adamson, Friedrich Garzarolli and Charles Patterson, 2009.

Charged Particle Bombardment of Zirconium Alloys — A Review (ZIRAT19/IZNA14 STR)

This Report reviews the effect of ion irradiation (or ion bombardment, used interchangeably in this Report) on not only the standard dimensional stability topics but also the full range of properties that can be influenced by ion irradiation. The primary questions addressed are: What properties of zirconium alloys can ion irradiated simulate (emulate or substitute for) neutron irradiation? How, or to what extent, can ion bombardment complement neutron irradiation?

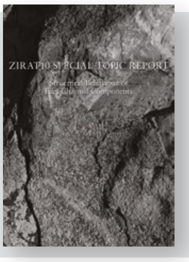
BWR Fuel Channel Distortion (ZIRAT16/IZNA11 STR)

This Report is primarily focused on channel distortion; that is, change of shape during in-reactor service: length, bow, bulge and twist. This Report addresses a broad range of channel features which can contribute to normal and problematic performance. In particular, the so-called “shadow corrosion induced” channel bow phenomena are analysed.



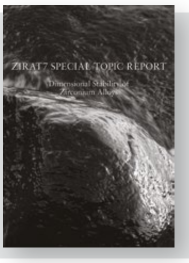
In-Reactor Creep of Zirconium Alloys (ZIRAT14/IZNA9 STR)

In this Report we have attempted to summarise data and mechanisms by addressing the variables that are known to affect irradiation creep. A number of conclusions are reached which give insight into the uses of creep data, mechanisms and models to assess in-service performance of reactor components.



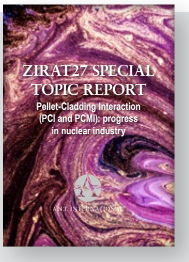
Structural Behaviour of Fuel Channel Components (ZIRAT10/IZNA5 STR)

The objective of this Report is to provide a better understanding of the mechanisms behind the dimensional changes of structural materials in LWRs and CANDUs. Such improved understanding may improve both fuel reliability and reactor safety.



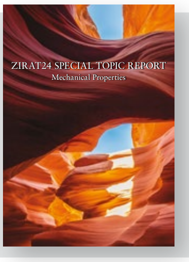
Dimensional Stability of Zirconium Alloys (ZIRAT7/IZNA2 STR)

This Report provides the understanding of the mechanisms of dimensional instability (including irradiation creep and growth) in the aggressive environment of the nuclear core and the potential effects on fuel performance.



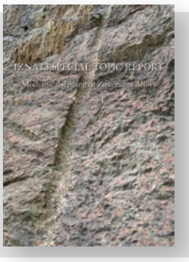
Pellet-Cladding Interaction (PCI and PCMI): progress in nuclear industry (ZIRAT27/IZNA22)

Pellet-Cladding Interaction (PCI) and Pellet-Cladding Mechanical Interaction (PCMI) remains an important phenomenon in the modern nuclear reactor fuel engineering. This topic was addressed in detail in ZIRAT-11 Special topical report on PCI issued in 2006. Since then, a substantial development has taken place, such as introduction of new cladding materials and additive fuel pellets. In addition to this, flexible power operation is being considered by many utilities worldwide. This introduces new challenges to the safe and reliable operation of the nuclear fuel. The report discusses up-to-date developments in the above mentioned areas and summarizes the main outcomes of the R&D work performed since 2006.



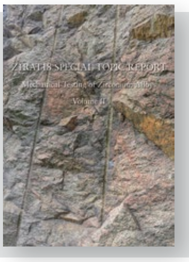
Mechanical Properties (ZIRAT24/IZNA19 STR)

This report is intended to provide basic understanding on the mechanical properties of zirconium alloys, stainless and ferritic steels and nickel alloys. The information can then be used by customers to evaluate their components.



Mechanical Testing of Zirconium Alloys — Volume I (ZIRAT18/IZNA13 STR)

This Report covers separate effects testing of Zr alloys.



Mechanical Testing of Zirconium Alloys — Volume II (ZIRAT18/IZNA13 STR)

This Report covers integral or specific phenomena testing of Zr alloys.

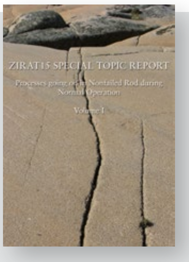
Pellet–Cladding Interaction (ZIRAT11/IZNA6 STR)

The objective of this Report is to give a better understanding of the PCI mechanisms, pertinent methods to test PCI performance and PCI remedy technology may improve fuel reliability and reactor safety.

Mechanical Properties of Zirconium Alloys (ZIRAT6/IZNA1 STR)

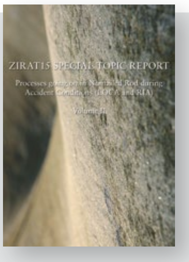
The objective of this Report is to provide the basic understanding of the mechanical properties of the fuel components that are crucial for the fuel in-pile performance.

Fuel Pellet (UO2 and MOX) Performance during normal operation and accident conditions



Processes going on in Nonfailed Rod during Normal Operation — Vol. I (ZIRAT15/IZNA10 STR)

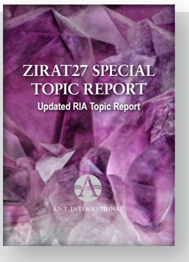
With increased burnup, processes going on inside a nonfailed fuel rod decrease pellet density, lower the fuel melting temperature and thermal conductivity, increase the fission gas release. Also, a high burnup structure is formed at pellet average burnups in excess of about 50 MWd/kgU. This Volume I of the Report describes the processes going on inside a nonfailed fuel rod during normal operation.



Processes Going on in Nonfailed Rod during Accident Conditions (LOCA and RIA) — Vol. II (ZIRAT15/IZNA10 STR)

This Report describes the fuel performance during accident conditions (RIA and LOCA). The associated Volume I of the Report describes the processes going on inside a nonfailed fuel rod during normal operation.

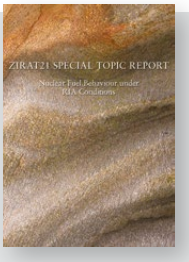
Fuel Performance during accident conditions (LOCA and RIA)



Nuclear Fuel Behaviour under RIA Conditions (ZIRAT27/IZNA22)

The content of the Updated RIA is basically the same as the original report (Nuclear Fuel Behaviour under RIA conditions published within the ZIRAT21/IZNA Programmes), see information below.

The main focus of this report is to give an update on two major subjects: (1) new RIA tests and the interpretation of the results and (2) new RIA related regulations. New RIA tests will complete the existing data base and their potential significance for RIA modelling or for RIA ruling. New acceptance criteria for RIA issued by US NRC are briefly described as well as some national approaches, different from the US NRC



Nuclear Fuel Behaviour under RIA Conditions (ZIRAT21/IZNA16 STR)

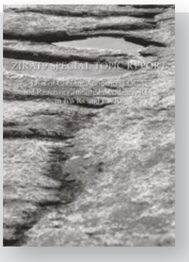
This Special Topic Report (STR) give insights and understanding of the parameters impacting the fuel RIA performance and reviews the applicability of the data to high burnup fuel cladding. Report describes the processes going on inside a nonfailed fuel rod during normal operation.

Effect of Hydrogen on Zirconium Alloy Properties — Vol. I (ZIRAT13/IZNA8 STR)

The intent of these two Reports is to discuss the basics of hydrogen, hydrides and their effect on the zirconium alloy properties in Volume I and in-pile performance during normal and accident conditions as well as dry storage in Volume II.

Effect of Hydrogen on Zirconium Alloy Performance (Normal Operation, LOCA/RIA and Dry Storage) — Vol. II (ZIRAT13/IZNA8 STR)

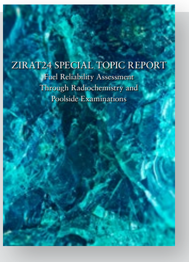
The intent of these two Reports is to discuss the basics of hydrogen, hydrides and their effect on the zirconium alloy properties in Volume I and in-pile performance during normal and accident conditions as well as dry storage in Volume II.



Loss of Coolant Accidents, LOCA, and Reactivity Initiated Accidents, RIA, in BWRs and PWRs (ZIRAT9/IZNA4 STR)

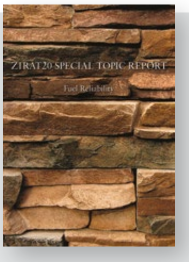
This Report gives insight and understanding of the LOCA and RIA issues and reviews the applicability of the relevant data. Specifically, the background data to the current (non-revised) LOCA criteria are discussed.

Fuel Reliability



Fuel Reliability Assessment Through Radiochemistry and Poolside Examinations (ZIRAT24/IZNA19 STR)

The primary objective of this report is to provide guidance in assessing fuel reliability for decisions regarding core operation, the cause of failure, returning fuel to the core for continued irradiation and of used nuclear fuel in dry storage containers. A secondary objective is to promote clear documentation of the state (intact or damaged) of all spent fuel assemblies or bundles for subsequent operations associated with the back-end of the fuel cycle.



Fuel Reliability (ZIRAT20/IZNA15 STR)

The Report provides information on how to increase fuel reliability by:

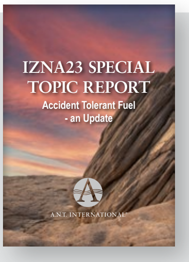
1. Reducing the primary fuel failure frequency and minimize the consequences of fuel failures when they occur and
2. Minimizing operational effects due to factors such as fuel assembly and channel bowing, that can affect thermal margins (LOCA, DNB, Dryout) and core control capabilities (control rod insertion).

Microstructure of Zr alloys and Effects on Performance

Microstructure of Zr Alloys and Effects on Performance (ZIRAT20/IZNA15 STR)

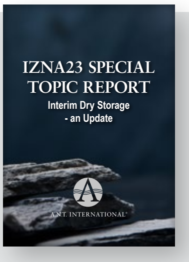
This Report provides examples illustrating how microstructures are modified during fabrication and service and how these microstructures affect in-reactor properties.

Other topics



Accident Tolerant Fuel: an update report 2020-2023 (ZIRAT28/IZNA 23)

During the last decade the development of various Accident Tolerant Fuel (ATF) concepts has come into focus of both research and industry communities in the USA, Europe and Asia. The accident tolerant fuel program is aiming towards improving the safety of nuclear energy by investigating materials that can replace or modify the current uranium-dioxide nuclear fuel and zirconium-based cladding. This research programs are being supported by all major nuclear countries since 2011. This updated version of the previously issued ANT International 2021 ATF report will provide the reader with a useful, quick but comprehensive overview of the latest ATF technical developments. It will give relevant information about ATF cladding and fuel, appropriate warnings and useful insights to nuclear fuel engineers and designers as well as to the fuel buyers.

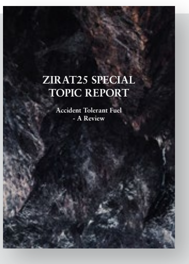


STR on Interim Dry Storage of Commercial Spent Nuclear Fuel - An Update (ZIRAT28/IZNA 23)

Except for a few countries (Finland, Sweden, France, and possibly Canada), the timing for establishing a geologic repository has been shown to be unpredictable. Therefore, spent fuel storage will remain the last backend operation for the foreseeable future in many countries. With proper attention, the radiological impact of storage is very low, but regulatory agencies have placed a heavy burden on licensees because of concerns related to the highly negative public perception related to the presence of spent fuel storage facilities in our biological environment. Therefore, locations where spent nuclear fuel (SNF) is or will be stored and their chosen storage technologies are the subjects of much scrutiny.

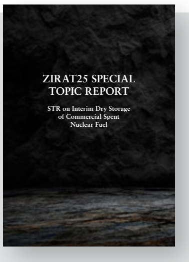
The focus of this review is on the spent nuclear fuel rods, and not on the storage system components such as the casks or the canisters and their internal hardware elements. More specifically, the following topics are treated in the report:

- Update of “Back-end” issues
- Thermal creep behaviour in relation to hydride reorientation
- PWR fuel rod cladding failure due to the hydrogen migration in spent fuel
- Update on any work on storage, transportation, long term issues
- Correlation between cooling rate and hydride reorientation. In particular, the case of fast cooling when the cask containing SNF is flooded with water, from a cladding temperature of ~350°C to ~30°C, is examined.



Accident Tolerant Fuel- A Review (ZIRAT25/IZNA20)

The purpose of this report is to present the most promising ATF concepts currently under development at various fuel vendors, research institutions and nuclear laboratories around the world and to provide the reader an independent assessment of the state of the art and potential for development and implementation related with each type of the ATF.

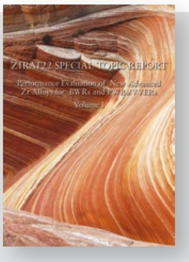


Interim Dry Storage of Commercial Spent Nuclear Fuel (ZIRAT25/IZNA20)

This Special Topic Report addresses the degradation mechanisms that could potentially affect the performance of spent fuel stored in a dry, inert environment for periods up to ~100 years. The focus of the review is on the spent nuclear fuel rods, and not on the storage system components such as the casks or the canisters and their internal hardware elements.

Material Test Reactors and Other Irradiation Facilities (ZIRAT23/IZNA18)

In materials test reactors (MTRs), materials are subject to intense neutron irradiation to study the induced changes. As MTRs are able to reproduce material degradation undergone by materials in power reactors, they provide essential support to the study of ageing of materials in power reactors. MTRs are also being used to irradiate new cladding materials and fuels that are being developed as Accident Tolerant Fuel (ATF) systems.

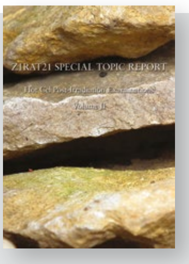


Performance Evaluation of New Advanced Zr Alloys for BWRs and PWRs/VVERs — Vol. I (ZIRAT22/IZNA17)

To meet the current situation with more aggressive reactor environments (higher burnups, changing water chemistries and loading patterns), and resolving fuel performance issues such as BWR channel bowing and PWR assembly bowing, a large number of zirconium alloys have been and are being developed. The main driver for the initial material development in Pressurised Water Reactors (PWRs) has been to reduce corrosion rates and Hydrogen Pick-Up Fractions (HPUFs), which have occasionally limited the maximum discharged burnup.

Performance Evaluation of New Advanced Zr Alloys For BWRs and PWRs/VVERs — Vol. II (ZIRAT22/IZNA17)

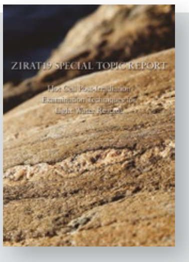
To meet the current situation with more aggressive reactor environments (higher burnups, changing water chemistries and loading patterns), and resolving fuel performance issues such as BWR channel bowing and PWR assembly bowing, a large number of zirconium alloys have been and are being developed. The main driver for the initial material development in Pressurised Water Reactors (PWRs) has been to reduce corrosion rates and Hydrogen Pick-Up Fractions (HPUFs), which have occasionally limited the maximum discharged burnup.



Hot Cell Post-Irradiation Examination Techniques for Light Water Reactor Fuels — Vol. II (ZIRAT21/IZNA16 STR)

This Report is a complement to the previous report on the same topic published within the ZIRAT19/IZNA14 Programme (Vol. I) The Report:

1. gives an overview of post-irradiation examination (PIE) and inspection techniques for CANDU nuclear fuel and other zirconium alloy components used in reactors;
2. discusses PIE techniques along with real world examples of in-reactor microstructural changes and impact on material behaviour;
3. provides information on PIE capabilities of some of the major hot cell facilities.

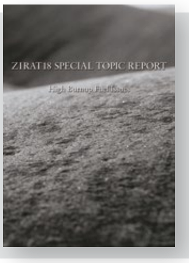


Hot Cell Post-Irradiation Examination Techniques for Light Water Reactor Fuel – Vol. I (ZIRAT19/IZNA14 STR)

This Report provides an overview about the status of post-irradiation examination (PIE) and inspection techniques for nuclear fuel and their applications for analysis of material degradation during fuel operation in a reactor core. Emphasis is given to advanced non-destructive and destructive PIE techniques applied to LWR fuel rods and bundle hardware. The objective of this Report is to provide this knowledge.

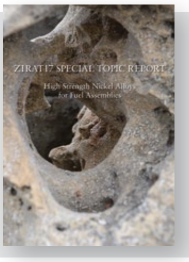
High Burnup Fuel Design Issues and Consequences (ZIRAT7/IZNA12 STR)

One of the major present challenges to nuclear energy lies in its commercial competitiveness. To stay competitive, the industry needs to maximise the availability and capacity factors of nuclear power plants while reducing maintenance and fuel cycle costs and enhancing safety. This special topic reviews the potential consequences of increased burnup on fuel. Recommendations are also given on how to remedy the high burnup issues.



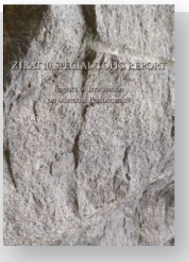
High Burnup Fuel Issues, their Most Recent Status (ZIRAT8/IZNA3 STR)

This Report reviews the potential consequences of increased burnup on fuel.



High Strength Nickel Alloys for Fuel Assemblies (ZIRAT17/IZNA12 STR)

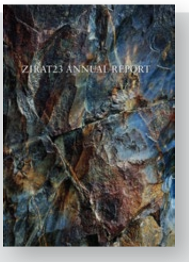
This Report is a comprehensive review and evaluation of the high strength nickel alloys (625, 718, X-750 and A286) used for PWR/VVER and BWR fuel assembly components.



Impact of Irradiation on Material Performance (ZIRAT10/IZNA5 STR)

This Report focuses on the behaviour of zirconium alloys used for the main structural components in the fuel bundle and should provide a solid understanding of the role that irradiation plays in component performance. This Report is a complementary companion to the Structural Behaviour of Fuel Components.

Annual Reports presenting key results published during 18 months



ZIRAT23/IZNA18
Annual Report
Covering the Zr related results published during 2017–2018

ZIRAT22/IZNA17
Annual Report
Covering the Zr related results published during 2016–2017

ZIRAT21/IZNA16
Annual Report
Covering the Zr related results published during 2015–2016

ZIRAT20/IZNA15
Annual Report
Covering the Zr related results published during 2014–2015

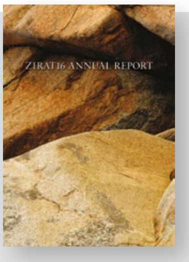
ZIRAT15/IZNA10
Annual Report
Covering the Zr related results published during 2009–2010

ZIRAT14/IZNA9
Annual Report
Covering the Zr related results published during 2008–2009

ZIRAT19/IZNA14
Annual Report
Covering the Zr related results published during 2013–2014

ZIRAT18/IZNA13
Annual Report
Covering the Zr related results published during 2012–2013

ZIRAT17/IZNA12
Annual Report
Covering the Zr related results published during 2011–2012



ZIRAT16/IZNA11
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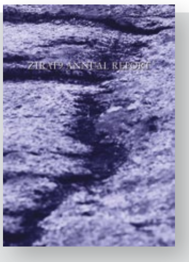
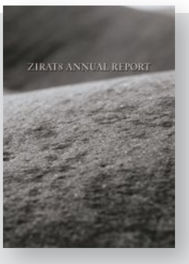
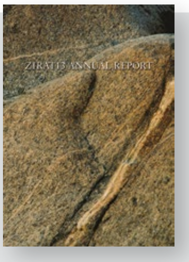
Covering the Zr related results published during 2010–2011



ZIRAT9/IZNA4
Annual Report
Covering the Zr related results published during 2003–2004

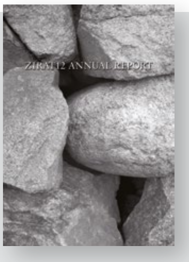


ZIRAT8/IZNA3
Annual Report
Covering the Zr related results published during 2002–2003



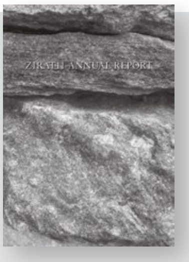
ZIRAT13/IZNA8
Annual Report

Covering the Zr related results published during 2007–2008



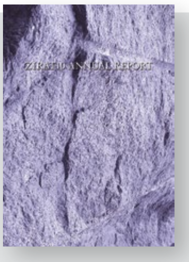
ZIRAT12/IZNA7
Annual Report

Covering the Zr related results published during 2006–2007



ZIRAT11/IZNA6
Annual Report

Covering the Zr related results published during 2005–2006



ZIRAT10/IZNA5
Annual Report

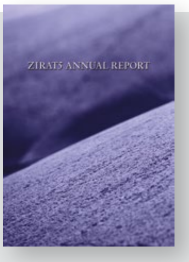
Covering the Zr related results published during 2004–2005

ZIRAT7/IZNA2
Annual Report

Covering the Zr related results published during 2001–2002

ZIRAT6/IZNA1
Annual Report

Covering the Zr related results published during 2000–2001



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