DELISA LTO

NEWSLETTER 01/2022

Dear nuclear energy enthusiasts,

You are just reading the first number of the DELISA-LTO project newsletter issued to professionals and the general public. This project deals with the safe lifetime extension of light water reactors (VVER) and the ageing of primary loop components with the aim to support the safe energy supply in Europe for next decades.

This newsletter provides you with basic information about the project, a description of planned or implemented work/events during the project, and much other information. We believe that you will find interesting information here and we will meet for the next newsletter.

Team DELISA-LTO

Project HORIZON-EURATOM-2021-NRT-01-01

Project end 31st May 2026

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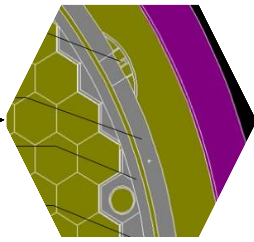
DEscription of the extended LIfetime and its influence on the Safety operation and construction materials performance – Long Term Operation with no compromises in the safety

VVER reactors

Thermal ageing

Non-destructive techniques



Modelling

Lifetime extension

Main Goals

The goals of the project is to increase operational safety and lifetime extension due to:

- Determination of the most critical components from the LTO point of view and description of the LTO effect on the material properties.
- Development of non-destructive techniques, simulation tools and their methodologies for early prediction of failures.
- The setting of recommendations for future NPPs operation and assessment of their lifetime extension.

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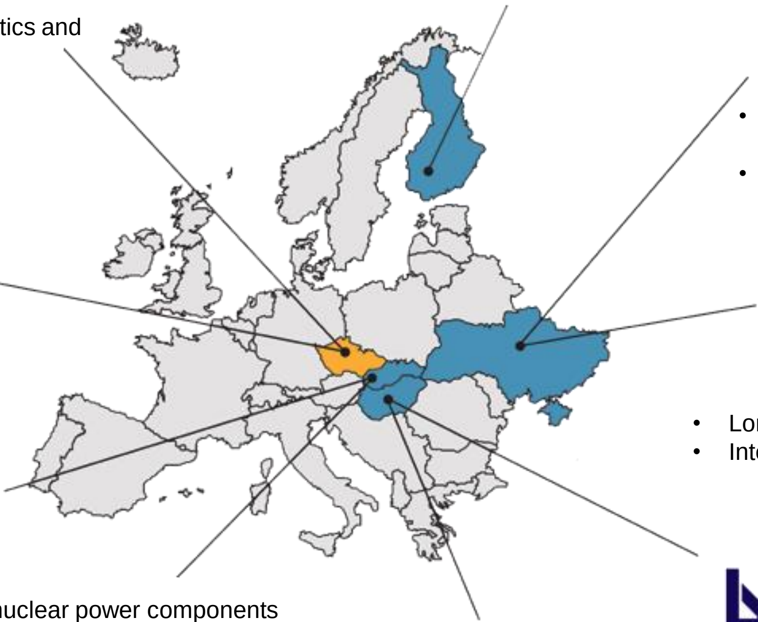
Project Consortium and involved Laboratories

CVŘ Research Centre Řež

- Department of Material and Mechanical Properties
- Department of Diagnostics and Qualification

VTT

- Department of Nuclear Reactor Materials
- Technology Platform Nuclear Technology



IPP CENTRE

- Department for Strength Calculations
- Department of Service of Chief Engineer

ÚJV NUCLEAR RESEARCH INSTITUTE

- Structural and Life Time Assessment Department
- Mechanical Testing Department
- Hot Cell Facility

SSTC NRS STATE ENTERPRISE STATE SCIENTIFIC AND TECHNICAL CENTER FOR NUCLEAR AND RADIATION SAFETY

- Long-Term Operation Department
- International Projects Department

vuje

- Division for diagnostics of nuclear power components
- Laboratory of microstructural analysis of material
- Laboratory of non-destructive testing of materials
- Laboratory for corrosion and mechanical tests

bay Bay Zoltán Nonprofit Ltd. for Applied Research

- Department of Structural Integrity and Production Technologies
- Material Testing Laboratory
- Digital Reality Laboratory

STU SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

- Laboratory of Non-destructive techniques, Institute of nuclear and physical engineering, Faculty of Electrical Engineering and Information Technology
- Laboratory of Structural Analyses, Faculty of Materials Science and Technology

Centre for Energy Research

- Fuel and Reactor Materials Department
- Laboratories with hot cell

Project Work Packages

WP1 - Project management (CVŘ)

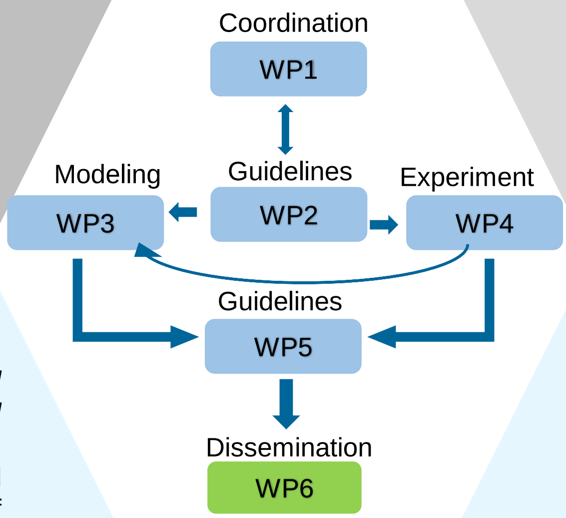
WP1 is dedicated ***to project coordination and managing*** all internal activities, i.e. planning of the project meetings, technical coordination of the project, communication between Partners and with the European Commission. WP1 monitors tasks with respect to the overall management of the project and the technical progress of the works.

WP2 - Methodology and assessment (VUJE)

WP2 collects the project Partners' wide experience and knowledge of the degradation of primary circuit components in VVER units and the skills in the testing of their material change. The goal of WP 2 is ***to indicate the most critical components*** and their parts in order for long-term operation and ***to propose methodology of material tests***.

WP6 - Dissemination, education and training (STUBA)

WP6 includes **dissemination and exploitation of results to the general public** and professionals, which is an important issue within the project implementation. WP6 will also support to transfer of knowledge to a new generation of technicians through effective education, training and organizing of workshops.



WP3 - Simulation and modelling (SSTC)

WP3 includes ***modelling and simulation of swelling and thermal ageing*** with the aim of understanding and predicting the behaviour of materials and components with different mechanical properties in different operational conditions and states that may change over time during long-term operation.

WP5 - Synthesis of the guidelines (EK)

WP5 is analysing the existing safety guidelines for available materials that could affect safe long-term operation expected for 60+ years. Based on the theoretical knowledge and results from WP2 - WP4, improving recommendations for procedures and techniques of testing and sample preparation will be formulated and submitted to authorities and vendors.

WP4 - Experimental validation and tests (UJV)

WP4 creates a solid and reliable basis of experimental data to evaluate of thermal ageing of materials during NPP operation. Results from the experiments will be used for the detailed assessment of degradation mechanisms' effects on selected structural NPP materials and for the determination of impact on current LTO procedures and methodologies.

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Investigated materials in DELISA-LTO project

Investigated materials were selected within the WP2 from different primary circuit components of the NPP Jaslovske Bohunice (Units 1 and 2) with respect to the structural material state (initial state/number of years in operation) and material type – base metal (BM), weld metal (WM) and heat affective zone (HAZ). The experimental matrix will also serve as a basis for the thermal ageing phenomenon evaluation, thus accelerated thermal ageing in laboratory conditions is also considered.

DELISA-LTO experimental data and metadata

During the DELISA-LTO project, the data about the material and their properties will be collected, stored and shared in Material Database of JRC. As shown in the following diagram (Figure 1, Table 1 and Table 2), individual test results will be accompanied by metadata (ancillary information) that puts the test result into context. This metadata includes source information (describing the provenance of the data); material pedigree data (of which there are two in the case of a dissimilar weld); specimen data; and test conditions. As depicted in Table 2, any single category (the material category in this case) consists of subcategories of data, each of which in turn will include many individual fields.

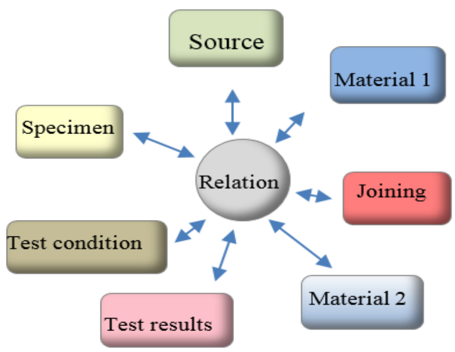

Figure 1 Metadata within the project.

Table 1 **C**haracterization of materials within the project.

Material entity	Hardness
Chemical composition	Microstructure
Design & production	Phase
Characterisation	Physical constants
Directionally solidified grain size	Thermo-mechanical heat treatment
Duplex grain size	Customer internals
Isotropic grain size	

Table 2 Plans of tests for the investigated samples.

MECHANICAL PROPERTIES	FATIGUE	THERMO-PHYSICAL PROPERTIES
CRACK GROWTH & FRACTURE	High cycle fatigue	Density
Creep crack growth	Low cycle fatigue (load control)	Electrical resistivity
Cyclic creep crack growth	Low cycle fatigue (strain control)	Emissivity
Fatigue crack growth	Thermal fatigue	Linear thermal expansion
Fracture toughness	Thermo-mechanical fatigue	Poisson's ratio
Impact	Creep-fatigue interaction	Specific heat
CREEP	IRRADIATION	Shear modulus
Cyclic creep	Irradiation swelling	Thermal conductivity
Multiaxial creep	Swelling	Thermal diffusivity
Torsional creep	In-pile relaxation	Young's modulus
Uniaxial creep	TENSILE	CORROSION
Small punch creep	Compression	High temperature corrosion
RELAXATION	Multiaxial tensile	COMPLEX TEXT
Multiaxial relaxation	Uniaxial tensile	
Uniaxial relaxation	Small punch tensile	

Summarizing the survey results, containing selected testing and analytical methods and parameters for the experimental program

WP4 team ***summarized the data from the survey of experimental methods in the Partners' laboratories*** *(Table 3)*, which can be used in the measurement of material samples from NPP Jaslovske Bohunice (Units 1 and 2) and others. After evaluating the collected data, it is possible ***to create a matrix framework of test materials*** that includes the priorities, preferences and testing capabilities of all participating laboratories. This output allows the use of available test methods and preferred specimen geometries in conjunction with available archival construction materials to develop a detailed system of ***experimental interlaboratory studies***. Thanks to the very close connection of the work packages, the obtained data will be used within WP4 - "Experimental validation and tests" as well as WP2 - "Methodology and evaluation".

Table 3 Overview about available testing and analytical methodologies in participating laboratories. Green cells indicate accredited methods.

Partner	CVR	IPP	STUBA	EK-CER	UJV	VUJE	VTT	BZN
A2.1 Impact testing	✓	✓	-	✓	✓	-	✓	✓
A2.2 Tensile testing	✓	✓	-	✓	✓	-	✓	✓
A2.3 Static fracture toughness	-	✓	-	✓	✓	-	✓	✓
A2.4 Hardness	✓	✓	✓	✓	✓	✓	✓	✓
A2.5 Small Punch test	-	✓	-	-	✓	✓	-	✓
A2.6 Scanning electron microscopy	✓	-	✓	✓	✓	✓	✓	✓
A2.7 Optical microscopy	✓	-	✓	✓	-	✓	✓	✓
A2.8 TEM	✓	-	✓	-	-	-	✓	-

Project Events

Past Events

Delisa-LTO on conferences:

- 8th International Conference of VVER 2022, 10th -11th October 2022, Řež, Czech Republic.
- Jaderné dny 2022, 14th -19th October 2022, Plzeň, Czech Republic.

Online workshop:

Moderní metody v diagnostice, testování a úpravě materiálů

Next steeps

Workshop for students and young professionals:

- Theme: Integrity Assessment of Main Structural Components Using Decommissioned Bohunice V1-NPP,
- Date: 6th – 10th February 2023,,
- Place: Kočovce, Slovak Republic.

More information will be soon on website.

Project Works

Works done

- **Signature of DELISA LTO Grant Agreement, no. 101061201**, 30th May 2022.
- **Project beginning,** 1st June 2022.
- **Kick-off meeting,** 28th – 29th June 2022 CVR, Řež - Czech Republic.
- **Website** www.delisa-lto.eu was launched on 4th November 2022.
- **Technical meeting WP2 & WP4**, Trnava - Slovak Republic, 21st -22nd November 2022.
- **Submitted Deliverable (WP4 Task2)** Report summarizing the survey results, containing selected testing and analytical methods and parameters for the experimental program, 30th November 2022.
- **Issued Scientific Publications** V. Slugen et al., Positron Annihilation Study of RPV Steels Loaded by Hydrogen Ion Implantation, Materials 15 (2022) 7091.
- **Abstracts in Proceedings** O. Srba, Long term operation (LTO) - current research directions, Presentation at 8th International Conference VVER 202, Session 4: LTO and maintenance, R&D, Řež -Czech Republic, 10th - 11th October 2022.

  V. Slugen, Advanced studies of irradiated VVER steels degradation, Presentation at 8th International Conference VVER 202, Session 4: LTO and maintenance, R&D, Řež -Czech Republic, 10th - 11th October 2022.

Next steeps

- **Preparation of cutting scheme of investigated materials** from Unit 1 and 2 Jaslovské Bohunice, May 2023
- **Distribution of materials to Partners' laboratories for measurement,** June 2023
- **Next Deliverables:**
  March 2022
  WP3 Task1: Report on normative approaches, current practice, and experience of RPV internals calculations (swelling evaluation) for LTO justification.

  May 2022
  WP2 Task1: Critical analysis of the primary circuit components important to LTO safe operation of NPP VVER 440 and VVER 1000.
  WP2 Task2: Database of the available materials.
  WP2 Task6: Report on applicability of ultrasonic measurement for the evaluation of phase changes caused by thermal ageing.
  WP4 Task4: State of the art on Thermal Ageing Evaluation.
  WP4 Task4: Detailed test matrix for the thermal ageing evaluation experimental program.

Related conferences to project in 2023

- **NDE in Nuclear 2023,** 27th- 29th June, Sheffield (UK)
- **ASME PVP 2023,** 16th – 21st July 2023, Atlanta (USA)
- **13th ECNDT 2023,** July, Lisbon
- **EUROMAT2023,** 3rd - 7th September, Frankfurt
- **DEFEKTOSKOPIE,** 24th -27th October, Berlin

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History of Long-term operation

While most of today's operating nuclear power plants (NPPs) were originally designed for between 30 and 40 years of operation, there is in fact no fixed technical limit to the lifespan of a reactor. Operation of NPPs beyond their design lifetime is now commonplace, with regulatory compliance, safety and economic performance being assessed on a case-by-case basis.

A significant milestone was reached in 2019 when the world's oldest operating NPP achieved 50 years of operation. The first reactor ever to accomplish this was Tarapur Unit 1 in India; this was joined soon after by Unit 2, and later by Beznau 1 (Switzerland), Nine Mile Point 1 (USA) and Ginna (USA). These are the first of many reactors which will cross this threshold in the coming years, and which will continue to generate clean reliable electricity for decades longer than originally anticipated.

Long-term operation (LTO) of NPPs has been successfully demonstrated and is increasingly recognised internationally as standard practice. The worldwide fleet of nuclear power reactors is becoming older. For example, the USA has one of the oldest fleets of NPPs, with most reactors already having had their operating licences renewed, allowing them to operate for a further 20 years beyond their initial 40-year operating licence period.

Despite their age, these NPPs continue to achieve outstanding performance with capacity factors of more than 90%. Many NPPs operators in the USA are now pursuing a subsequent licence renewal which would permit them to operate their NPPs for a total of 80 years.

History of VVER reactors

VVER (water-moderated/ water-cooled reactor) is a type of pressurized water reactor designed and developed in the former Soviet Union by OKB Gidropress. Electrical output of these reactors is 440-1200 MW. The materials used for VVER reactor pressure vessels (RPV) vary in detail with its type and place of manufacturing. There were 3 plants: Izhora near St. Petersburg, Atommash on the Volga and at the Škoda plant in Pilsen in the Czech Republic.

The first two VVERs were the 70 MWe unit at Rheinsberg and the 210 commissioned in 1963 at Novovoronezh. These were followed by a second prototype 365 MWe operated in 1969. From these prototypes came a standard 440 MWe NPP that was designated the VVER-440-V230. Usually, built-in modules of twin units, have six loops, isolation valves on each loop, horizontal steam generators and all use 220 MWe steam turbines. The first VVER-440 V230 was Novovoronezh Unit 3, which began power operations in 1971. The two Armenian units are a variation of this model which includes anti-seismic features.

The RPVs were welded by an automatic submerged arc using Sv-1OKhMFT welding wire and AN-42 flux. Up to 9 RPVs from produced 16 are not clad with stainless steel: Kola 1 and 2, Armenia 1, Novovoronezh 3 and 4, Kozloduy 1 and 2 and Greifswald 1 and 2. Only limited evaluation of the initial properties was carried out for these reactors, consequently, there is but limited data and no archive material now available for.

A later type VVER-440 V213 was introduced in the 1970s. The main difference between the V213 and the V230 is in the provision of mitigation for the effects of severe accidents. These reactors contained surveillance specimens for advance information about the state of the RPVs and when specimens in the first 'chains' were tested a significant difference between actual and assumed mechanical properties was observed — where the change in properties was greater than had been assumed.

	V230	V213	V320
Mass (t)	215	215	320
Length (m)	11.8	11.8	10.9
Diameter (m)	3.84	3.84	4.535
Wall thickness without clad (m)	0.145	0.14	0.193
Working pressure (MPa)	12.26	12.26	17.65
Design pressure (MPa)	13.7	13.7	13.7
Hydrotest pressure (MPa)	17.1	19.2	24.6
Design wall temperature (°C)	325	325	350
Vessel life (years)	30	40	40
Water inlet temperature (°C)	268	268	289
Water outlet temperature (°C)	296	296	322
Number of loops	6	6	4

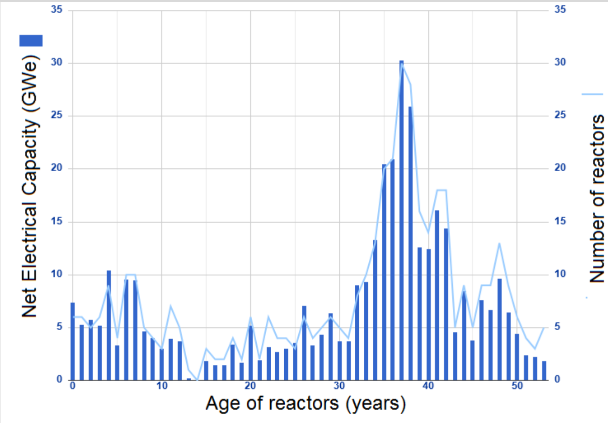
The newest type of VVER reactor is VVER-1000 with reactor vessels V-302 and V- 320. The first of this 1000 MWe type became operational in 1980 at Novovoronezh (unit 5). These are usually built-in modules of twin units, all have four loops, horizontal steam generators and all use 1000 MW steam turbines. The welds of some VVER 1000 have a nickel content of up to 1.9 wt.% an

Short news

Reactors ageing in the world

To November 2022, in total 427 power reactors are in operation and 56 new reactors are under construction worldwide. The age distribution is presented in Fig. 1 From this amount, 65 VVER reactors are in operation in 12 countries and about 20 VVERs are under construction. In EU countries, 19 VVER units are in operation. The next 12 are in Ukraine. The high level of safe, effective, reliable, and long-term operation (LTO) behind the projected lifetime with lifetime extension up to 60-80 years and without a former general designer is the real and actual challenge for the European nuclear community.

Figure 2 Age distribution of operating reactors world-wide.



Source: IAEA website,cit. 30th October, 2022
https://pris.iaea.org/PRIS/WorldStatistics/OperationalByAge.aspx

Conference VVER 2022

A special session dedicated to VVERs long-term operation leaded by prof. Vladimir Slugen from STUBA was organised in frame of the 8th International conference VVER 2022 in Řež at Prague on 10th -11th October. Detailed information is available at https://www.vver2022.com/. The DELISA-LTO project as well as actual trends in VVERs research was presented by Mr. Ondrej Srba from Research centre Řež.

The VVER 2022 conference is the triennial international meeting of experts from nuclear power plants with VVER reactors, representatives of regulatory bodies and authors of energy strategies, designers, fuel suppliers, maintenance, and other services for units in operation.

The youngest reactor VVER 440

VVER unit in Mochovce (Slovakia) reached its first criticality on 22nd October 2022. The controlled fission chain reaction is already underway in the reactor, although the reactor power is still very close to zero. The power operation is expected at the beginning of next year. We wish all the best and long-term operation to the 3rd Mochovce reactor!

Figure 3 Reactor hall of Mochovce 3.

For more information:

Delisa Lto

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Website: www.delisa-lto.eu

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Feel free to forward this Newsletter to friends that can be interested to be informed about DELISA-LTO Project or log-term operation of NPPs.

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