DELISA LTO

NEWSLETTER
04/2024

Dear nuclear energy enthusiasts,
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 the next decades.

This newsletter follows Newsletter no. 03/2023 and provides the basic information about the project and description of done or planned work/events during the last 6 months of the Project from January to June 2024. We believe that you will find interesting information here and we will meet for the next newsletter.

Team DELISA-LTO

Lifetime extension

Thermal ageing

VVER reactors

Funded by the European Union

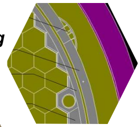
Project HORIZON-EURATOM-2021-NRT-01-01

DELISA LTO

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

Project period: June 2022 – May 2026
Reporting period: January 2024 – June 2024

Material testing



Modelling

Education

Main Goals of the Project

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.

Works done in the project (since January 2024)

Project Meetings

- **2nd Annular meeting**, 25th – 27th June 2024, Helsinki, Finland.
- **Project Management Board meeting**, 14th May 2024, online.
- **Meeting of the harmonization committee**, 27th May 2024, online.
- **WP2&4 technical meeting**, 15th – 16th February 2024, Bratislava, Slovakia.

Submitted Deliverables (M18-M24)

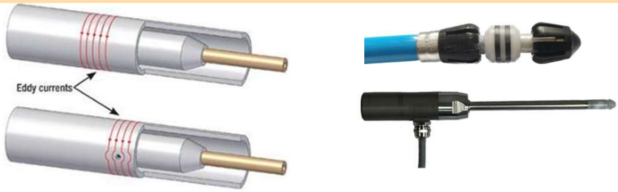
- **WP2 - D2.3:** Report on operational experience and NDT techniques, May 2024.
- **WP2 - D2.4:** Report on indications of selected V1 SG tubes, May 2024.
- **WP2 - D2.5:** Methodology of the structural and substructural changes for evaluation of thermal ageing processes, May 2024.
- **WP2 - D2.8:** Methodology of mechanical testing for evaluation of thermal ageing processes, May 2024.
- **WP2 - D2.10:** Sample preparation and transport, May 2024
- **WP5 - D5.2:** Task report summarizing the survey results, containing the literature review, collection of the guidelines based on the key SSCs, May 2024.

Operational Experience and NDT Techniques (D2.3)

Heat-exchanging tubes in steam generators are one of the most affected components by the long-term operation of WWER reactors. These tubes, with a nominal wall thickness of only 1.4 mm (WWER440) or 1.5 mm (WWER1000), are subject to a variety of degradation factors. These include increased power output, extended operational periods, secondary water chemistry, and often mechanical impacts from repairs such as dissimilar welds (DN1100). As steam generator tubing is a critical component that significantly limits the lifespan of many units, the inspection tools and maintenance should be well-optimized.

Work Package 2 of the DELISA-LTO project documents the operational experiences related to non-destructive testing (NDT) of heat-exchanging tubes in Slovakia, the Czech Republic, Ukraine, and Hungary. This WP also involves the experimental validation of Eddy Current Testing (ECT) techniques on a comprehensive matrix of steam generator samples, facilitating the transfer of application experience with these techniques to different countries operating WWER reactors.

Fig. 1 Principle of ECT and typical Bobbin probe design and High speed Motorized Rotating Pancake Coil probe.



Slovakia:

The experience in Slovakia showed that common locations for the degradation of heat-exchanging tubes include the tube support plates and the tube-collector region (transition area). The prevalence of external defects and deposits has been primarily observed in the hot legs. Different ECT techniques and probes are used for inspecting steam generator tubes (SGTs). The SGT check is performed with a standard coil probe from VUJE, a.s. In-service inspection of the heat exchange tubes in the collector area is carried out with the MRPC (SOROTEC) probe from Tecnatom. One of the main criteria for plugging the tubes of the heat exchanger of the steam generator JE WWER-440 is when the indication detected by the bobbin probe exceeds 66% of the wall loss. The high-speed Motorized Rotating Pancake Coil technique was introduced in 2022 for in-service inspections of the heat exchange tubes in the collector area.

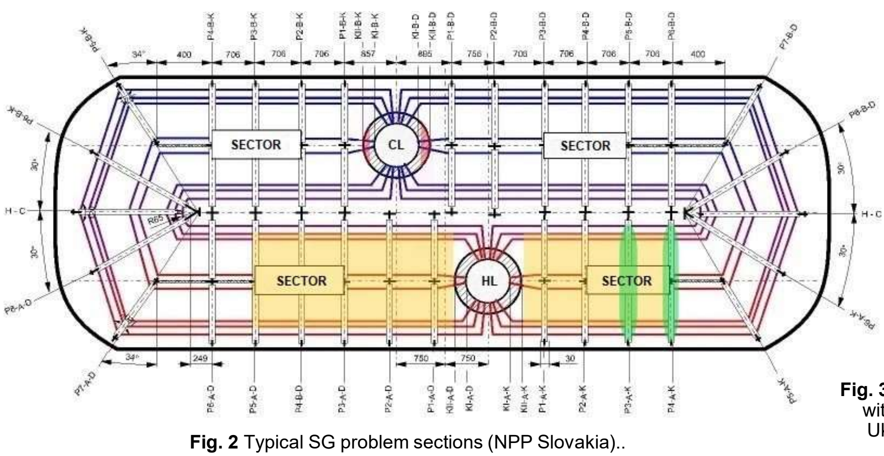


Fig. 2 Typical SG problem sections (NPP Slovakia)..

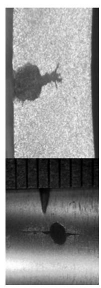


Fig. 3 SCC associated with pitting(South Ukrainian NPP).

The Czech Republic

In the Czech Republic, the predominant location for SGT defects is the free span area. The accelerated degradation of SGTs is evident at the Dukovany NPP due to the plant's age and the approach to aging management in recent years (chemical regime, deposits, sludge, etc.). Mechanical cleaning of deposits is one corrective measure to mitigate ageing. The collector interface is verified by Motorized Rotating Pancake Coil, X-probe, and Array probe techniques. SGTs with indications greater than 60% thinning are plugged.

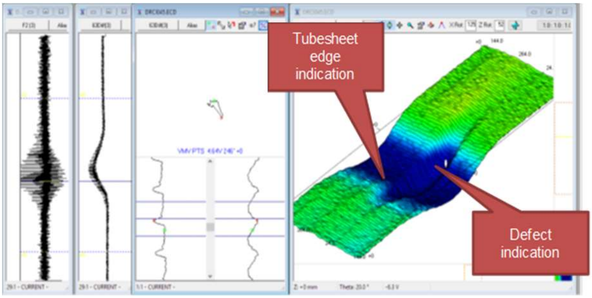


Fig. 4 Critical area – indication of defect.

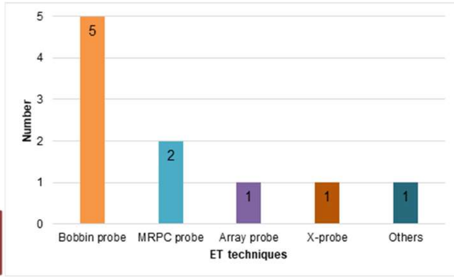


Fig. 5 Graphical display of the use of inspection techniques for in-service inspection of SGTs by various WWER operators.

Ukraine:

In Ukraine, the corrosive effects of water in the secondary loop are a significant factor in SGT degradation due to mechanical stress, corrosive elements (chlorine ions), and an oxidizing agent (oxygen or copper oxide). Typical locations of degradation include under support plates, free span, under deposits, and in the collector. ECT is used for periodic testing (at least once every four years). Initially, suboptimal decision-making led to premature HET plugging or defective HET operations, causing leaks and unplanned shutdowns. Tubes are subject to plugging if a defect with ECT characteristics of Amplitude ≥ 0.8 V and Phase Measurement (PM) ≥ 65% or PM ≥ 85% (regardless of amplitude) is detected, else smaller defects are periodically observed and reevaluated.

Hungary:

In Hungary, periodic non-destructive testing by ECT-bobbin probe is conducted. Most detected indications initiated on the outer surfaces of the tubes in the tube support plate, with some defects also located in the free span. According to the ECT requirements for the heat exchange tubes of the SG, the registration limit is a 20% deep ECT indication from the circumferential flaw of the outer diameter. An indication exceeding 50% is considered the defect limit, which is also the criterion for plugging. All observed cracks were confirmed as Outside Diameter Stress Corrosion Cracking. Penetrations through the walls closely matched ECT predictions. At Paks NPP, chemical cleaning was performed to remove deposits and reduce the corrosion environment.

The interval for In-Service Inspection (ISI) of SGTs is six years in Slovakia and the Czech Republic and four years in Ukraine and Hungary. Collective data indicates that the prevailing degradation mechanisms on heat-exchanging tubes are Stress Corrosion Cracking (SCC) and pitting.

References:

Lukasevich B.I., Trunov N.B., Dragunov Yu.G., Davidenko S.E. Steam generators of WWER reactor installations for nuclear power plants. - M.: ICC "Akademkniga", 2004. - 391 p.

Davidenko S.E. Development and implementation of guidelines on the problems of testing of heat-exchange tubes of steam generators in reactor plants with WWER // Annual report of JSC OKB "Gidropess" for 2013. Issue. fourteen.

P.Z. Lugovoi, O.P.Shugailo, Y.D. Kruglii, R.I. Moskalyshyn. Impacts the wears on the stress and strain state of steam generators heat exchanging tubes // INTERNATIONAL APPLIED MECHANICS. - 2021, Volume 57, No2. - P. 70-83

Indications of Selected Steam Generator Tubes (D2.4)

In Steam Generators (SGs) design, a deliberate surplus of approximately 20% of the heat exchange surface area was factored in. This surplus provides operation even if a certain number of pipes are damaged and need to be sealed. The correct choice of materials and construction quality when designing steam generators (SG) and maintaining high-quality water chemistry during operation ensures high resistance against most types of damage, manifested on individual parts of the SG.

Corrosion represents the most serious problem on the SGs as corrosion-active salts can settle in steam generators and form deposits (sludge) on heat exchange surfaces (Fig.1) The influence of the environment's chemistry was manifested mainly by the damage in the area of support plates, the free span of the SG tubes (SGTs), and the gap area of the tube. The outer surface of the heat exchange tubes of the steam generator can be covered with a layer of oxidic deposit material of varying thickness called sludge. It is a layer of corrosion products located on the outer surface of the pipe in an area with reduced secondary water circulation.

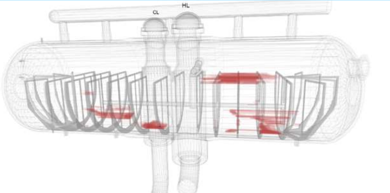


Fig. 6 View of the sludge in the steam generator.

Fig. 7 SGTs for the experimental program WP4/ Task 4.3.

Historical data indicates that operational damage SGTs predominantly occurred on the outer surface of the tubes, specifically on the side facing the secondary circuit due to corrosion, but also on the inner wall of the SGTs, within the primary circuit, which were typically associated with manufacturing-related factors - such as folds or localized deformations. Thus, the Eddy current testing (ECT) is an optimal investigation technique as it can observe and distinguish - the external defects from the secondary circuit side and the internal defects from the side of the primary circuit. ECT can also find local mechanical deformation of the tube wall and shape due to the manufacturing process, and localise free ferromagnetic particles inside the tubes, indirectly indicating the development of operational damage.

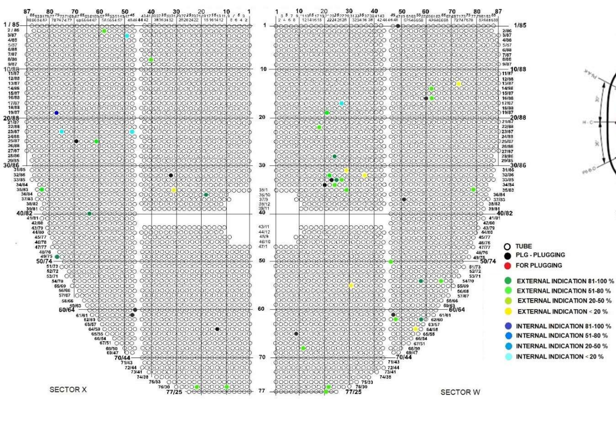


Fig. 8 Hot collector tubesheet of the SG11(year 2004).

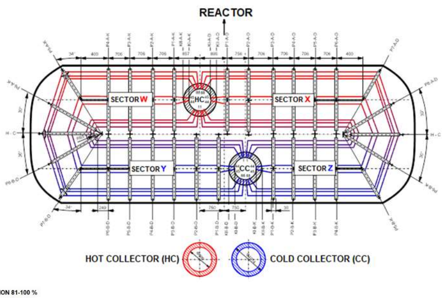


Fig. 9 Support system layout of the steam generator body SG11.

Investigated SGTs from V1 NPP Bohunice

As part of the DELISA-LTO project, materials obtained during the decommissioning of NPP Bohunice V1 were integrated into the experimental program, including heat exchange tubes from the steam generator containing real defects from NPP Bohunice V1. The choice of experimental material, i.e., heat exchange tubes from the steam generators, was primarily influenced by time constraints, low radiation levels, low dose rates, and contamination considerations. Based on these factors 26 fragments of heat exchange tubes from SG11 and SG13 of V1 NPP unit 1 were selected. The experimental program is conducted as a round-robin test (RRT) to yield comparable results for subsequent integration into industrial non-destructive testing (NDT) in-service procedures and methodologies.

At NPP Bohunice V1, an increased pH (9.2) was allowed, maintained by ammonia at the upper limit of the recommended value. Due to the good degassing of the feed water, hydrazine was not dosed during the stable operation. The appropriate dose of hydrochloric acid (<0,01 mg/kg) stabilized the chemical regime in the circulating water and suppressed the formation of deposits on the SGs heat exchange surfaces and corrosion of the circuit, which caused the following corrosion problems in condensers. NPP Bohunice V1 did not have the condensate polishing system, but its addition was ensured by investment in 1989.

The total number of plugged SGTs of the first unit of JE V1 was 29 pieces, while the maximum number of plugged tubes was in SG11 (15 tubes) and SG13 has no plugged tubes.

Results from ECT

The final report from ECT measurements from the last maintenance and testing before the decommissioning of Unit 1 in 2004 reported mostly the measurements from the hot side of the tubes of the steam generator SG11, where most of the indications (defects or precursors) were identified. The number of pipes with indications of a characteristic decrease in wall thickness was 39. The number of already plugged pipes in the past was 12. Unquantified indications were also detected as manufacture defects (tube shape and wall thickness) and free ferromagnetic particles. At the same time, the inspection of the heat exchange tubes confirmed the indications found in 2000. The inspection of the SGTs of the SG11 in 2004 in the W sector registered three new indications (one internal indication and two external indications), which were consequently plugged before the last campaign.

plugging. All observed cracks were confirmed as Outside Diameter Stress Corrosion Cracking. Penetrations through the walls closely matched ECT predictions. At Paks NPP, chemical cleaning was performed to remove deposits and reduce the corrosion environment.

Upon analysing the data about SG11 and SG13, it also became evident that operational damage to the SGTs predominantly was manifested on the exterior surface, originating from the secondary circuit side. Conversely, defects found on the inner walls of the SGTs within the primary circuit primarily take the form of manufacturing-related issues, such as folds and alterations in permeability (ferromagnetic particles - sludges).

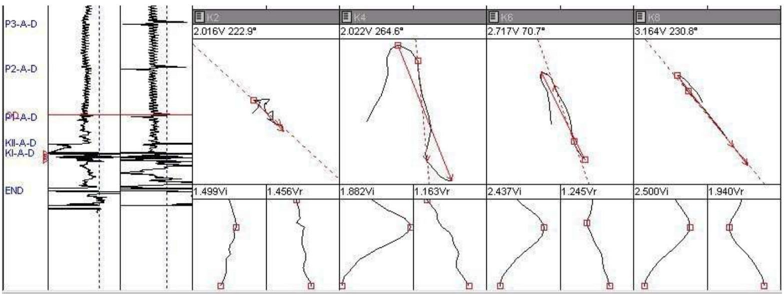


Fig. 10 Fragment SG3.9/51 – the eddy current signal course of the external indication.

All 26 fragments indicate some characteristic tube wall loss and their severity is shown in Table 1 by marking 'E'. These indications were quantified as the external types and are associated with operational tube damage, such as corrosion cracking or pitting. In Table 1, there is information on the amplitude [V], and phase [°] of these indications, as well as the corresponding tube wall loss [%]).

It's worth noting that all indications on fragments from SG11 and SG13 in sectors W and X were situated within the support area. Fragment SG3.9/12 and fragment SG3.9/32 come from heat exchange tubes plugged in 2004. The remaining tubes were not plugged at that time, as they did not meet the plugging criteria in effect.

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For SG11, a decrease in wall thickness within the range of 81% - 100% measured by the ET method was recorded on 24% of the heat exchange tubes out of a total of 21 pieces. Similarly, for SG11, a decrease in wall thickness within the range of 51% - 80% measured by the ET method was recorded on 57% of the heat exchange tubes out of a total of 21 pieces, while a decrease in wall thickness within the range of 20% - 50% measured by the ET method was recorded on 19% of the heat exchange tubes out of a total of 21 pieces.

Tab. 1 Quantified indications list of HET SG11 a SG13, NPP Bohunice V1.

Fragment mark	Sect.	Column	Row	Ampl. [V]	Phase [°]	Depth [%]	20-50%	51-80%	81-100%	Note
SG3.9/12	W	58	54	4,13	59	94			E	SG11
SG3.9/13	W	66	54	1,30	89	73		E		SG11
SG3.9/15	W	62	14	0,97	82	79		E		SG11
SG3.9/16	W	29	31	0,93	120	45	E			SG11
SG3.9/18	W	27	33	2,66	99	66		E		SG11
SG3.9/19	W	24	34	1,10	84	79		E		SG11
SG3.9/20	W	29	35	1,10	83	79		E		SG11
SG3.9/21	W	77	35	0,85	95	70		E		SG11
SG3.9/22	W	21	77	1,42	97	67		E		SG11
SG3.9/25	W	22	32	1,67	96	68		E		SG11
SG3.9/28	W	48	62	0,85	90	72		E		SG11
SG3.9/29	W	56	64	1,96	118	44	E			SG11
SG3.9/30	W	12	68	1,92	82	79		E		SG11
SG3.9/32	W	24	28	3,30	76	84			E	SG11
SG3.9/33	W	31	55	1,12	115	50	E			SG11
SG3.9/34	W	58	62	0,82	75	83			E	SG11
SG3.9/3	X	18	36	1,32	79	84			E	SG11
SG3.9/4	X	64	40	1,82	71	89			E	SG11
SG3.9/5	X	22	76	0,70	95	72		E		SG11
SG3.9/8	X	31	35	0,96	121	44	E			SG11
SG3.9/9	X	10	76	1,59	108	59		E		SG11
SG3.9/46	X	6	70	1,05	91	73		E		SG13
SG3.9/48	X	67	53	1,09	111	54		E		SG13
SG3.9/49	W	19	31	2,18	65	88			E	SG13
SG3.9/50	W	36	32	1,94	89	69		E		SG13
SG3.9/51	W	61	51	2,43	97	69		E		SG13

SGTs plugged

Sample preparation and transport (D2.10)

At the DELISA-LTO Project, the primary impetus was to harness the potential of harvested materials sourced from the decommissioned Jaslovske Bohunice Nuclear Power Plant (NPP). The decommissioning of its two V1 units in Slovakia presented a unique opportunity to obtain materials that had undergone approximately 28-29 campaigns of real operational conditions, providing invaluable insights into long-term operation (LTO). As the project evolved, the archival materials expanded to components sourced from the Paks NPP in Hungary and VVER 1000-type reactors in Ukraine. These strategic points aimed at enhancing the diversity and comprehensiveness of materials available for the DELISA-LTO experiments.

The final works within Working Package 2 (D2.10) submitted in Month 24 of the project, provide an activities summarization undertaken for sharing and transporting of materials among all project partners. The successful implementation of activities leading to the cutting and transportation of materials between the project partners was carried out under the leadership of VUJE based on careful planning and after continuous communication with the partners in the DELISA-LTO project.

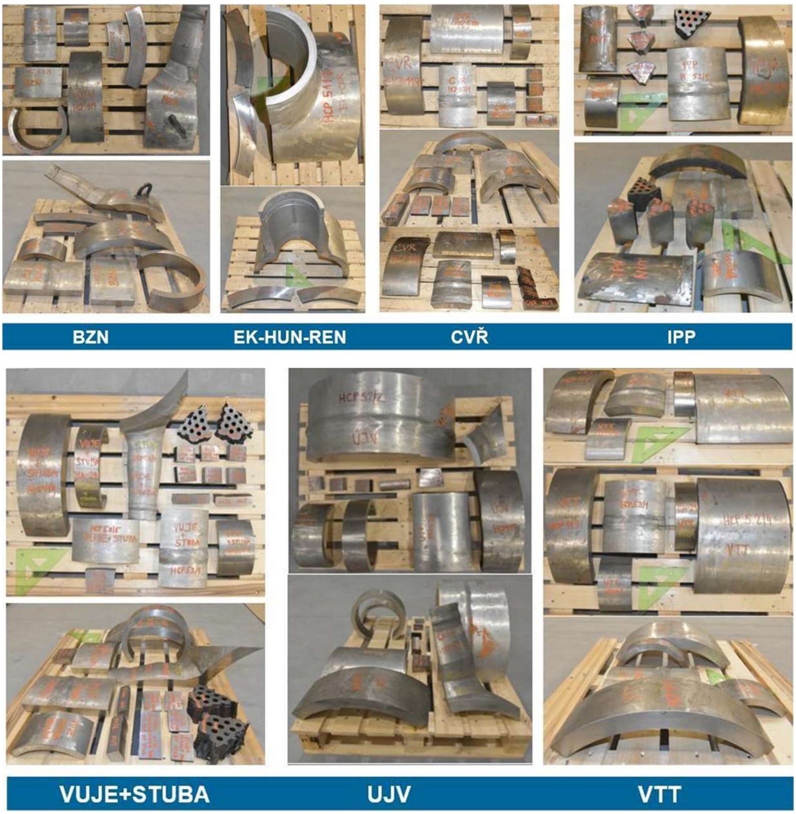

Fig. 10 Material for transport to the Partners.

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DELISA-LTO Workshop II

Workshop on ***Application of non-destructive testing (NDT) methods in characterization of long-term treated NPP design materials*** will be held from 10th to 14th February 2024 in Mansion Kočovce (Slovakia). The workshop is intended for University students and young professionals in the field of nuclear engineering and technology.

The workshop will include presentation from experienced lectures from the practice and universities. The theoretical part will be supplemented by practical measurement with application of non-destructive techniques at Slovak University of Technology in Bratislava, Trnava and Jaslovske Bohunice, and with technical visits of NDT laboratories in VUJE and Slovenske elektrarne. The social program will include visit of SPA Piestany or other local cultural attractions.

More information together with the application form will be available from September 2024 on www.delisa-lto.eu .

Fig. 11 Non-destructive techniques at STUBA.

Life in Consortium

WP2&4 meeting, Feb 2024.

Bratislava, Feb 2024.

Helsinki, June 2024.

Annular meeting, June 2024.

Next Deliverables

- **D3.3** Report on benchmark of swelling evaluation (July 2024)
- **D3.5** Report on Thermal Ageing Evaluation and impacts on LTO (March 2025)

Next events

- **The 9th European Nuclear Industry Congress 2024,** 16th-18th September 2024, Paris, France.
- **Conference PWR, LTO session,** 8th-9th October 2024, Prague, Czech Republic.
- ***Technical Meeting on Safety Aspects of LTO Peer Reviews During the Early Stages of Operation***, 5th- 8th November 2024, Vienna, Austria.
- **General Assembly meeting**, online, December 2024.
- **Nuclear Power Plant Long-Term Operation Summit 2025,** 22nd-24th January 2025, Andermatt, Switzerland.
- **Delisa-LTO Workshop II**, 10th-14th February 2025, Kočovce, Slovakia.

For more information:

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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.