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Experiences from Construction of Olkiluoto 3 Nuclear Plant in Finland

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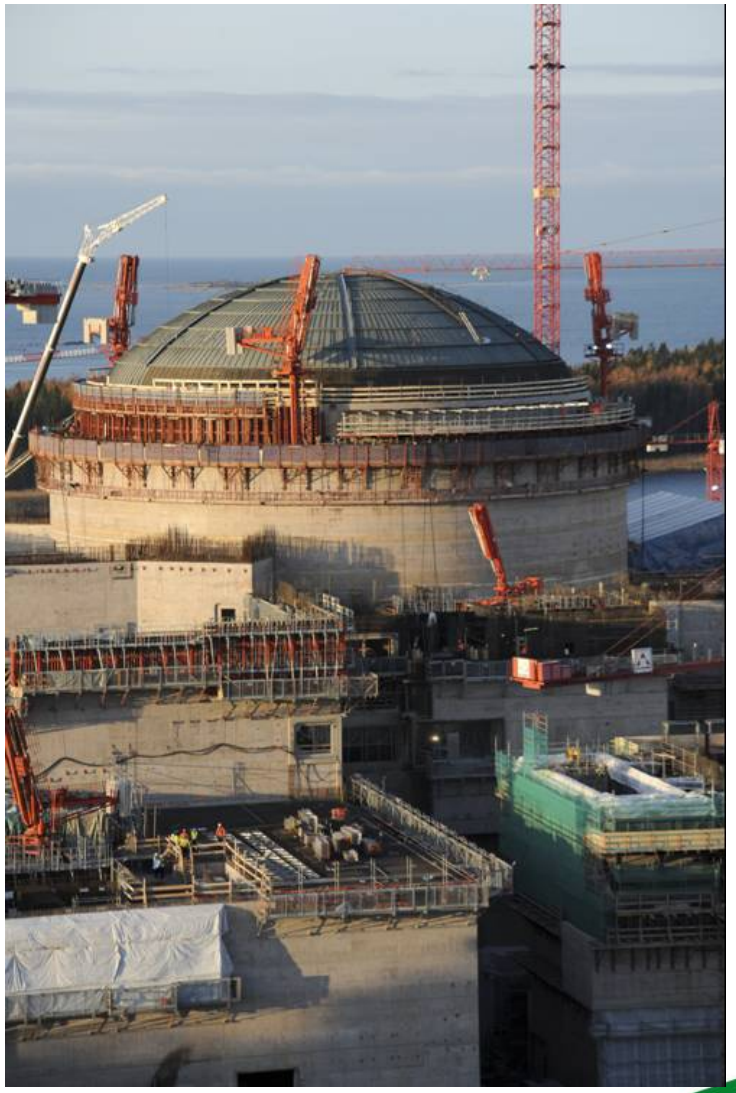
Operating reactors in Finland

	Net power MWe	Start of operation	Licensed until	Cumulative production TWh	Lifetime load factor %
Loviisa 1	**488**	**1977**	**2027**	**120**	**86**
Loviisa 2	**488**	**1980**	**2030**	**110**	**89**
Olkiluoto 1	**860**	**1978**	**2018**	**191**	**92**
Olkiluoto 2	**860**	**1980**	**2018**	**175**	**93**

- *Loviisa reactors are of VVER-440 type, initial net power 440 MWe*
- *Olkiluoto reactors are of BWR type, initial net power 660 MWe*

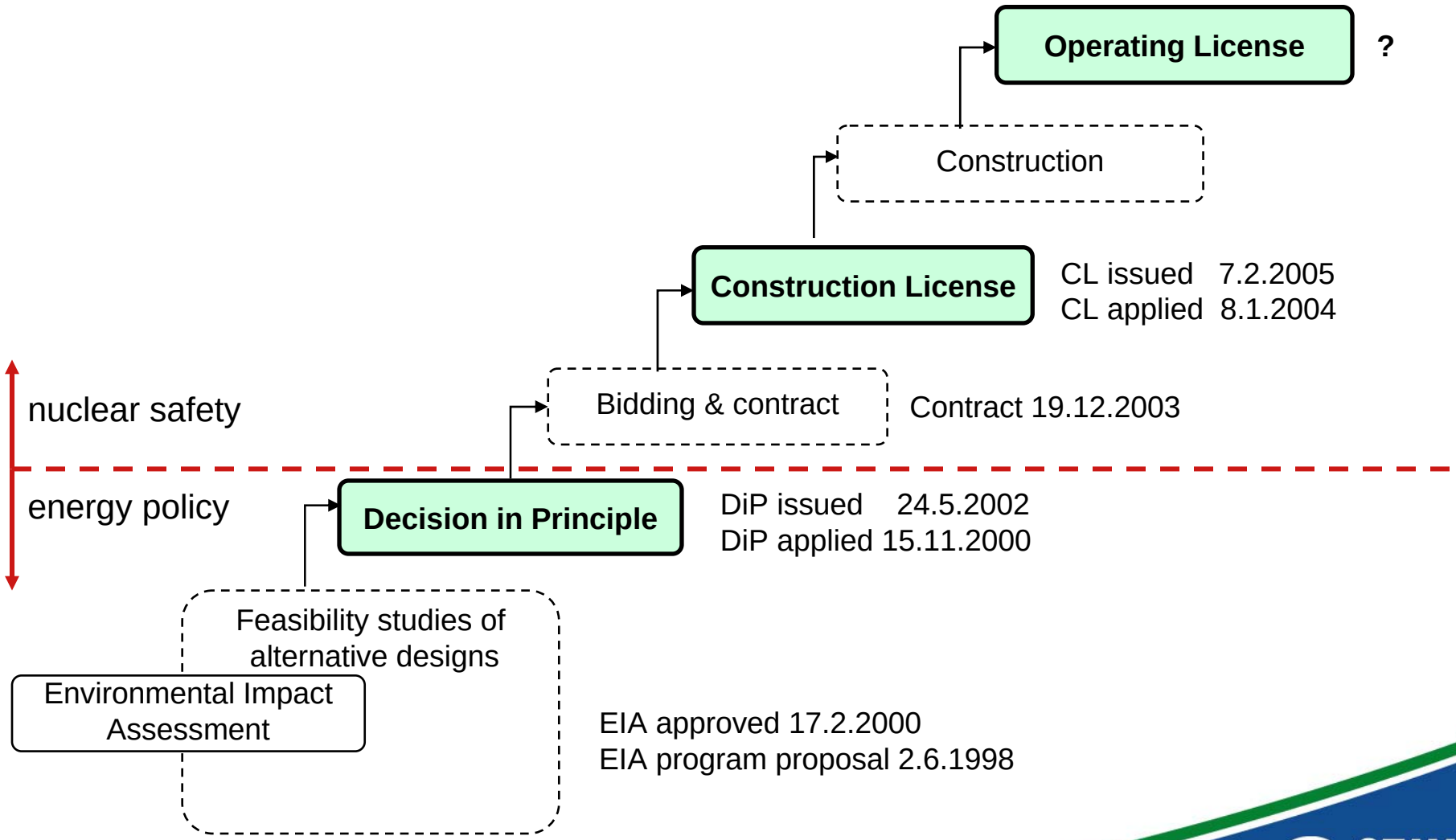
Olkiluoto 3 (OL3) Project

- OL3 is the first EPR being constructed
- OL3 is a turn key project
  - Vendor is the Consortium of Areva and Siemens
  - Owner and operator (Licensee) is TVO



Photos: TVO

Licensing schedule of Olkiluoto 3



Challenges of nuclear new build

- Starting nuclear new build in Europe after a long suspension has been demanding:
  - Olkiluoto 3 construction started very slowly because the construction permit was granted 14 months after signing the contract, and the vendor was not yet adequately prepared;
  - large unit size, new advanced design features, and new technologies brought additional challenges for implementation;
  - nevertheless, construction has progressed reasonably well since the working design for buildings was completed and the construction site was properly organized.
- As opposite to some virulent public propaganda, the Olkiluoto 3 project is not a warning example but has provided valuable lessons for subsequent projects.

Situation of parties at time of contract: Areva

+ Areva had the necessary economic resources for recruiting new staff for the project and a capability for relatively quick restart of nuclear build.

+ Conceptual design was based on extensive operating experience and long-time development effort, and was supported with relevant experimental research in France and Germany.

- Areva did not have earlier experience as a turn-key contractor – in its earlier NPP projects it had always been in a more limited role, contributing reactor island design and equipment as part of a larger consortium.

- Areva's staff had been strongly reduced from time of earlier construction, especially the number of designers was too small for quick start.

- Many of the experienced nuclear manufacturers had left the business – it was necessary to find new subcontractors and to coach them in the nuclear business.

Situation of parties at time of contract: TVO

+ TVO had long-time experience from NPP operation and had implemented several modernization and power up-rate projects over the years.

+ TVO had co-operated actively since 1980's with ABB Atom for developing an advanced new BWR design and had conducted feasibility studies with other vendors

+ TVO could use European Utility Requirements in its call for tenders, these had been developed in more than 10 years' time by leading nuclear utilities in Europe

- TVO's staff did not have hands-on experience from management of a large construction project

- TVO was not adequately aware of the decreased capabilities of the vendors and the actual status of the available designs – target set for construction time in call for bids was not realistic.

Lessons learned – reasons for delay

The schedule of Nuclear Island is now about three years behind the original plan. Main reasons for delay are:

- too ambitious original schedule for a plant that is first of its kind and larger than any NPP built earlier
- inadequate completion of design and engineering work prior to start of construction
- shortage of experienced designers
- lack of experience of parties in managing a large construction project
- worldwide shortage of qualified equipment manufacturers

Construction of Turbine Island has progressed much better

- there is close co-operation between the Turbine Island vendor and an experienced construction company, resulting in good integration of design and construction work
- installation of main equipment at Turbine Island was already completed – about one year behind original schedule

Lessons learned – change of NPP construction environment (1)

In planning and scheduling new build, it is necessary to recognize that circumstances in Europe and the USA are quite different from 1970's when most of the currently operating plants were constructed:

- vendors of 1970´s had large experienced organizations, with comprehensive in-house capability for design and manufacturing – less need for subcontractors
- there was enough of skilled manufacturing capacity in the market
- designs were often based on work done earlier in similar projects
- experienced project managers were available

The situation in Japan and Korea seems to be different – vendors have been constructing without a break and have short supply chains in design, manufacturing, and construction

Lessons learned – change of NPP construction environment (2)

Vendors and their sub-contractors have lost much knowledge and skills when experienced experts have retired, and also new type of competence is needed for new technologies

- good company name earned in the past is no guarantee for success but more important is the experience and competence of persons assigned to the project

Vendors need to establish new sub-contractor networks from companies with proven skills

- awareness of nuclear quality and understanding of nuclear safety culture must be taught to companies that have no previous nuclear experience
- management of work conducted by sub-contractors is a challenge of its own

Lessons learned – preparation of project (1)

Early contacts between vendors, licensee and regulator are helpful

Feasibility studies of several designs in early stage of the project were found very useful and facilitated subsequent licensing process.

- crucial safety issues were identified before and during the DiP process; these issues could be addressed before bidding

Each design proposed in bidding was improved from the original version that was reviewed tentatively during the DiP process.

Lessons learned – preparation of project (2)

Making safety requirements clearly understood is necessary to avoid surprises during construction

TVO used European Utility Requirements (EUR) to present the technical requirements to potential bidders

- EUR did not include all national safety requirements.

The licensee and the regulator need to discuss early enough on how the national safety requirements be best presented in the call for bids.

Lessons learned – preparation of project (3)

Understanding of regulatory practices is essential for successful project implementation

In Finland, the regulatory practice is different from what Areva had met elsewhere.

For ensuring smooth progress of the project, all parties (vendor, licensee, regulator) should be familiar with the licensing, regulatory oversight, and inspection practices in the vendor country and in the customer country.

Lessons learned – preparation of project (4)

Preparedness of all parties must be ensured before starting the project implementation

In order to avoid delays and difficulties in the project implementation, it is necessary to allocate enough time for planning stage and to assess the preparedness of each party before starting construction

Before starting, each of the parties (vendor, licensee, regulator) should assess whether

- licensee's capabilities and resources are adequate
- vendor's capabilities and resources are adequate
- the design has been done to a detailed level, as required for a controlled construction start and for smooth implementation
- qualified subcontractors are available as needed, and plans and contracts exist for managing the subcontractor chains

Lessons learned – preparation of project (5)

Both the licensee and the vendor must have:

- project management and quality management skills
- experience from management of a large construction project
- knowledge and experience in all technical areas relevant for nuclear safety: civil, mechanical, electrical, and I&C engineering, and nuclear technologies (water chemistry, nuclear fuel, reactor physics, thermo-hydraulics, safety analysis)
- skills and arrangements to verify achievement of required quality
- arrangements to control and correct quality non-conformances

In addition, the vendor must have:

- experienced designers who have a realistic view on the actual challenges involved in implementation
- access to manufacturers and constructors who have proven capability to meet designer's intent and related specifications

Lessons learned – preparation of project (6)

Experience and skills needed for successful construction management

- how to schedule the work,
- how to organize the construction site,
- what resources are needed and when,
- how the vendor can find competent contractors and how it should manage them, and
- how the licensee should conduct its oversight.

In making contracts for construction, one should not underestimate the importance of proven experience from large projects.

Lessons learned – preparation of project (7)

Importance of timely completion of design

Inadequate completion of design and engineering work prior to start of construction is detrimental to implementation of the project in targeted schedule:

- it delays the start of construction activities at full speed
- it causes continuous pressures to all involved organizations
- it leads to attempts to reschedule manufacturing and construction steps, thus making project management complicated
- it leads to reduced quality due to time pressure and often requires corrections and reassessment

Lessons learned – preparation of project (8)

Commendable timing of design steps (1)

Conceptual design – before bidding

- safety design criteria
- layout of buildings, process diagrams of main systems and key parameters for main equipment

Basic design – before construction license application

- safety analysis
- loads for design of buildings, specification of system parameters and limits for protection system
- diagrams of main systems, drawings of main buildings, 3D-drawings of main fluid systems and structures

Lessons learned – preparation of project (9)

Commendable timing of design steps (2)

Detailed design – in parallel with CL review and completed not later than about two years after construction start

- designs specifications of all components
- diagrams of all systems, drawings of all buildings, 3D-drawings of all fluid systems and structures

Working design – started well before construction start

- shop drawings for manufacturing, architectural drawings and specifications for construction

Lessons learned – management of subcontractors (1)

For ensuring good management of the subcontractor chains, it is important that in each call for tender for sub-contracts the vendor clearly indicates and emphasizes the nuclear specific practices, such as

- a requirement to provide design documentation well in advance of planned manufacturing,
- multiple quality controls and regulatory inspections to be conducted during manufacturing, and
- expectations on safety culture.

If the nuclear specific practices are not recognized and understood by the sub-contractors at the time of signing the contract, difficulties are to be expected in a later stage.

Lessons learned – management of subcontractors (2)

It has been noted that

- the real competence of manufacturers and sub-contractors is not easy to judge through auditing only
- evaluation of the manufacturers ability at the shop floors is important
- the vendor needs to ensure that its sub-contractors require the same nuclear quality standard through the entire supply chain

The licensee needs to have means to ascertain that

- the issues specific to nuclear safety and quality management, and the respective controls are properly agreed in each contract between the vendor and its sub-contractors, including the entire supply chain.

Lessons learned – communication within the vendor consortium

If design work is conducted by different organisations and in different places (or even in different countries), good coordination and communication is vital for successful outcome.

Licensee and regulator should audit and carefully assess the communication approach and adequacy of communication between those designers who are expected to interact during the design process.

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Lessons learned – mastering the manufacturing technologies

New advanced safety features are not easily implemented

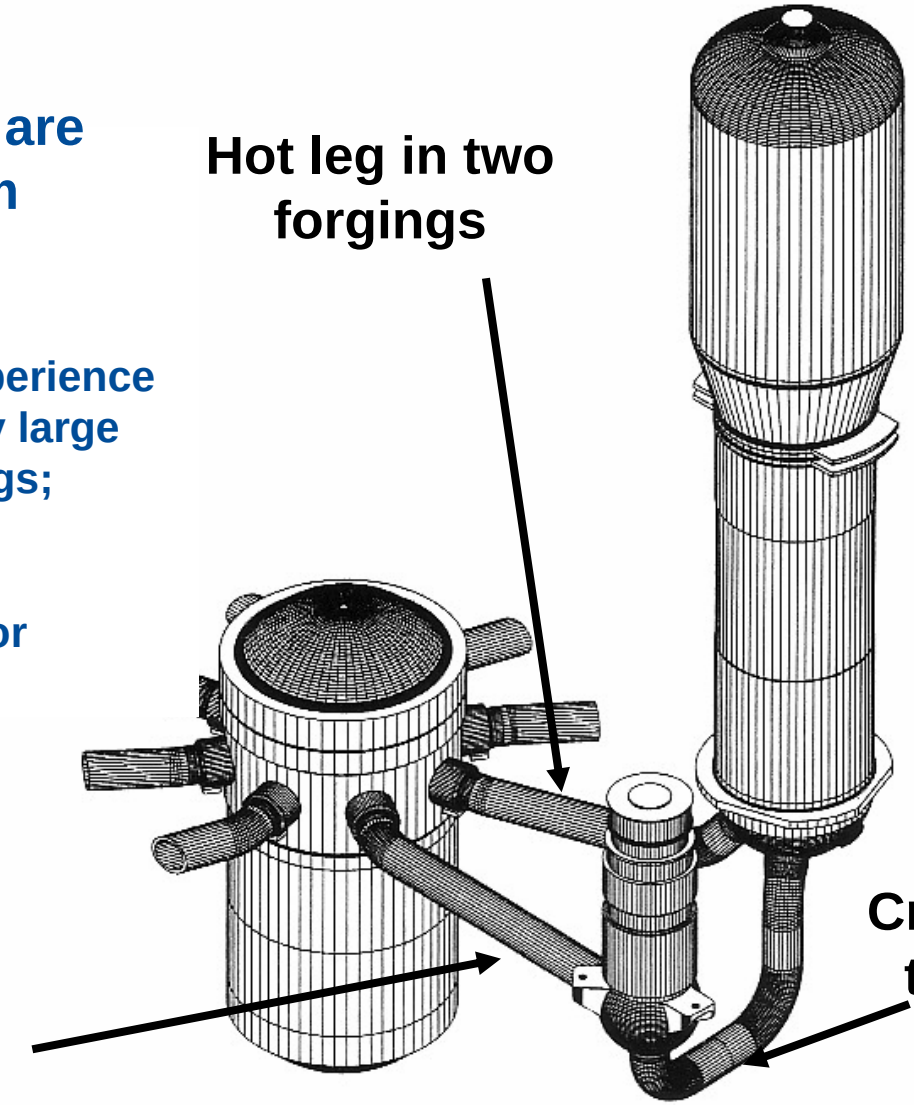
Qualification of a new construction or manufacturing method may take time if it is not done before the project start. For instance:

- new welding solutions were a challenge during RPV manufacturing, and additional evaluation and some repair welding were needed

Many components for Olkiluoto 3 had to be re-manufactured to achieve acceptable quality and to ensure 60 years lifetime

Main coolant loops are made with minimum number of welds

There was no earlier experience in manufacturing of very large main coolant line forgings; re-manufacturing was necessary to reach finer grain size, as required for in-service-inspections



Paineastia ja yksi neljästä kiertopiiristä höyrystimineen

Final Forging of Cold Leg (weight ~ 160 t)

weight after approx. 1 year of machining work ~ 15 t

First Cold Leg after Construction Inspection

Test piece – nozzle and safe-end

Lessons learned – licensee responsibility (1)

Licensee is responsible for the safety of its plant when it starts to operate

- Licensee must have strong control also of the construction phase of the project - turn key and fixed price project is not different in this respect
- respective roles and responsibilities of Licensee and Vendor need to be specified accordingly

Licensee management needs to be committed to build and implement

- a strong quality management system and
- a high safety culture already during the construction time

Safety culture cannot be turned on overnight at the plant start-up !

Lessons learned – licensee responsibility (2)

Licensee shall

- conduct its own safety assessment to verify that the plant and its SSC's are licensable,
- have its own requirement management system and an independent capability to verify and prove that all requirements are met, with support of a third party where necessary
- have a system for reporting and resolving all non-conformances identified in quality controls
- have an opportunity to require use of proven state-of-the-art technology in manufacturing and construction (not only to accept final products that meet minimum agreed quality requirements)

Lessons learned – safety culture during construction (1)

Strong message and transparent actions and decisions are expected from the management of the Vendor and the Licensee to promote safety culture: ***"safety and quality have higher priority than costs and schedule"*** .

Management needs to demonstrate their attitude in

- choice of qualified subcontractors
- state-of-the-art tools and methods
- uncompromising compliance with the agreed requirements
- walk downs by management

Lessons learned – safety culture during construction (2)

Questioning attitude is needed on every working level and in each organisation

- licensee, vendor, subcontractors.

Safety concerns and questions by workers need to be responded properly.

Each person attending the project needs to understand the safety significance of his / her work, to promote personal responsibility.

Lessons learned – importance of regulatory oversight of construction

Throughout the OL3 project there have been multiple quality controls, carried out by the Manufacturers / Constructors, Areva, TVO and STUK. Therefore the product deviations have generally been detected with high sensitivity.

Nevertheless, in some situations the QC inspectors by the Manufacturer, Vendor, and Licensee are facing too much economic pressure, and may not be in a position to enforce stopping of work and making necessary corrections, even when the work is not progressing as expected - in such situation an intervention by a regulatory inspector is needed

Stringent regulatory approach and inspections are thus needed to verify that new manufacturing techniques and new type of equipment meet the specifications set by the designer.

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Conclusions (1)

Starting new build is demanding because much of the earlier experience and resources have been lost from the nuclear industry.

Adequate time has to be allocated to good preparation of the project before actual construction start:

- making design as early as needed for smooth construction,
- qualifying the new design features and technologies,
- building competent organizations,
- specifying responsibilities of parties,
- ensuring availability of qualified designers, constructors and manufacturers to implement the project, and
- resolving potential regulatory uncertainties.

Conclusions (2)

During the construction of Olkiluoto 3 we have found that close monitoring and oversight by both TVO (licensee) and STUK (regulatory body) is necessary to ensure achievement of specified quality.

Encouraging progress has been made during the project, and after the “teething problems” the construction has proceed well. However, in the first piping installations at the Reactor Island, enforcement actions were again needed to make the welders follow the specifications given in the procedures.

While there have been many non-conformances and re-manufacturing needs, the quality awareness and pro-activity of the licensee and the manufacturers have been at a reasonably good level. The corrective actions have been taken in line with the QA/QC practices specified for the project.

Conclusions (3)

The final quality in Olkiluoto 3 structures and components has not been compromised; but in some cases achieving and proving expected quality has required

- extensive and time consuming tests and inspections to prove that the required standards have been met
- extensive new analysis
- re-manufacturing of some equipment

The observed difficulties at the construction stage have not influenced the safety of the power plant when it will be ready to operate.

Additional information

- Additional information on the Finnish way and experience:
  - STUK and IAEA will organise in Helsinki
    - **TRAINING COURSE ON SAFETY AND REGULATION OF NUCLEAR POWER PLANTS, 23 - 27 August 2010**
    - **WORKSHOP ON EXPERIENCES FROM OLKILUOTO 3 NPP CONSTRUCTION AND ITS REGULATORY OVERSIGHT, 30 August - 3 September 2010**
  - Invitation and information is on the website www.stuk.fi

Thank you for your interest !