Nuclear Technology Improvements in Modernization, Refurbishment and New Build Projects in Finland

Harri Tuomisto
Fortum, Finland

OECD/NEA Workshop on Innovations in Water-cooled Reactor Technologies
11-12 February 2015, NEA Headquarters, Issy-les-Moulineaux, France

CONTENTS

- Loviisa VVER-440 and its lifespan
- Plant modifications
  - Internal and external hazard management
  - Severe Accident Management
  - Fukushima modifications
- Olkiluoto BWRs
- New plant concepts
- Loviisa 3 and nuclear cogeneration option
- SMR and GenIV

Loviisa VVER-440

- Owned and operated by Fortum
- Commissioning
  - Loviisa 1 in February 1977
  - Loviisa 2 in March 1980
- Operation licenses until
  - Loviisa 1: 2027
  - Loviisa 2 : 2030
- Gross (net) efficiency
  - 2 x 520 (496) MW
- Power generation since 1977: 256 TWh
- Load factor 92.5% (2013)

Life span of the Loviisa NPP

1969-1981 Planning, construction and commissioning phase

- Main contracts signed and construction permit in 1970
- Construction started 1971, commissioning in 1977 and 1980

1981-2004 Period of major safety modifications and upgrades

- TMI-modifications, reactor pressure vessel upgrades, emergency feedwater, primary-to-secondary leakage management etc.
- Modernization and power upgrading 1997
- Severe Accident Management implementations

2004-2030… Plant life management phase

- I&C renewal 2004-201x
- Fukushima modifications
- Current operating licenses up to 2027 and 2030 (50 yrs.)

Plant modifications at Loviisa NPP after commissioning

- Improving protection against internal and external hazards (1980-2003)
- SAM Programme including hardware modifications (1986-2004)
- Modernization and power upgrading with 9% (1996-1997)
- Plant life management: **I&C renovation** (ongoing)
- Fukushima modifications (ongoing)
  - Ultimate heat sink with air cooling (independent of sea water)
  - Assessing the protection of excessively high sea level
  - Battery and diesel fuel capacity will be increased
  - Guidelines for long-lasting accident situations that affect both plants

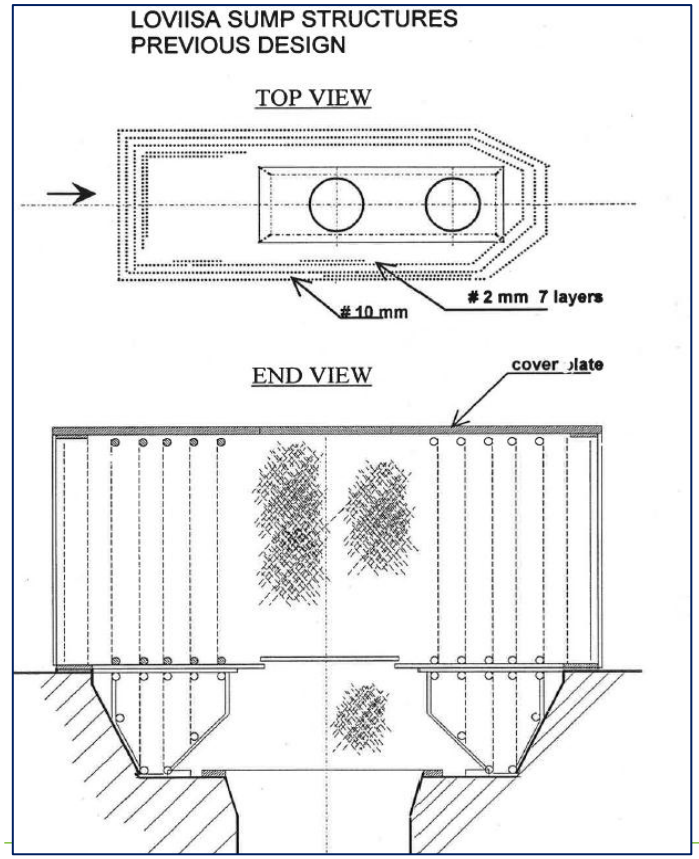
- Radioactive waste management:
  - Interim storage for spent nuclear fuel
  - Deep repository for low and intermediate level waste
  - Liquid waste solidification plant

Protection against Internal and External Hazards (1980 - 2003)

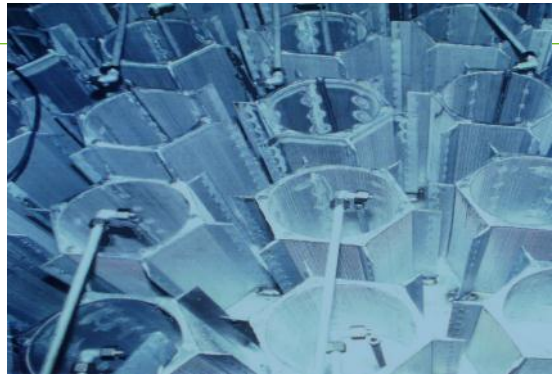
- **modifications after Three Mile Island**: hydrogen monitoring and igniters, improved PORV, solution to the "loop seal" issue
- measures against **pressurized thermal shock (PTS)** of the reactor pressure vessel: introduction of dummies to the core periphery, heating up the ECCS water, modifying the ECCS capacity, additional I&C, and finally thermal annealing of the pressure vessel of unit 1
- new **autonomous emergency feedwater** system, particularly to manage turbine hall fires
- new containment **sump strainer** designs to prevent sump clogging by insulating materials
- management of primary-to-secondary leakage accident (**PRISE**): PZR spray, safety valve upgrades, increased tank capacity for feeding SGs
- management of **inhomogeneous boron dilution**
- protection against **frazil ice** in cooling channels

Evolution of sump strainers

Initial design 1978:
sumps protected by screening nets



Modification after Barsebäck event (early 90's):



Modified protection against fuel assembly blockages (early 2010's)

Top level SA critical safety functions at Loviisa

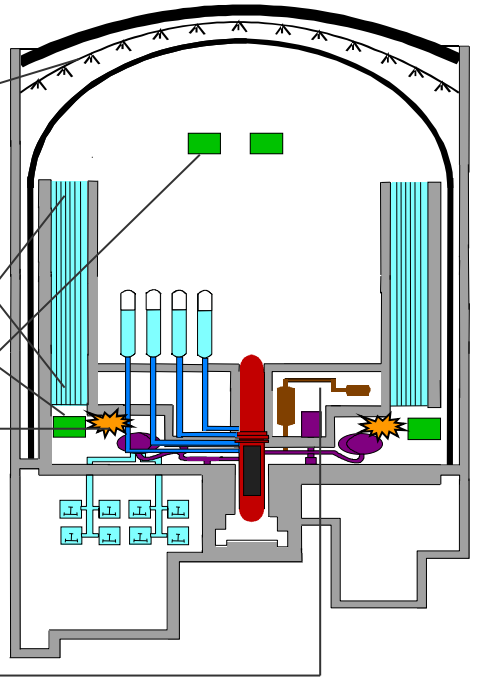
SAM safety function	Measures
Ensuring containment isolation	**Dedicated I&C**
Primary system depressurization	**Dedicated relief valves**
Absence of energetic events: hydrogen combustion	**Hydrogen management strategy** - **Mixing of the containment atmosphere (forced opening of the ice condenser doors)** - **PARs (upper and lower compartment)** - **Igniters (lower compartment)**
In-vessel melt retention by external cooling	**IVR strategy by cavity flooding**
Long-term containment heat removal (overpressure protection)	**External containment spray**

Implementation of SAM at Loviisa 1990-2004

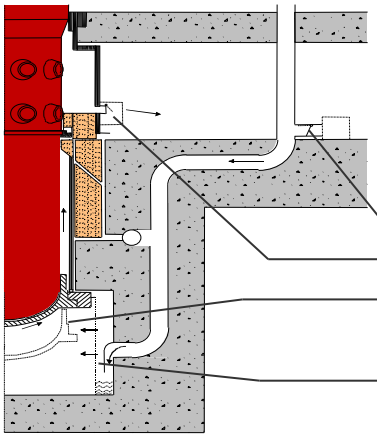
Long-term containment cooling with external spray of the dome

Hydrogen mitigation
- **Forcing the ice condenser doors open**
- **Catalytic recombiners**
- **Igniters (glow-plugs)**

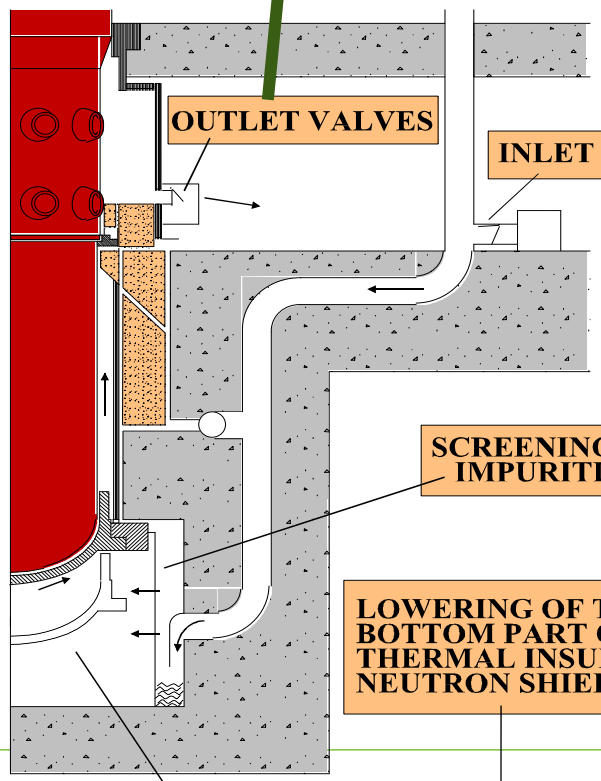
Depressurization of the RCS

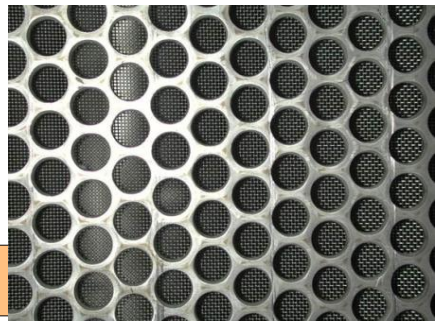


Containment isolation
- Manual backup
- Local control centres
- Monitoring of the isolation success
- Monitoring of the leakages



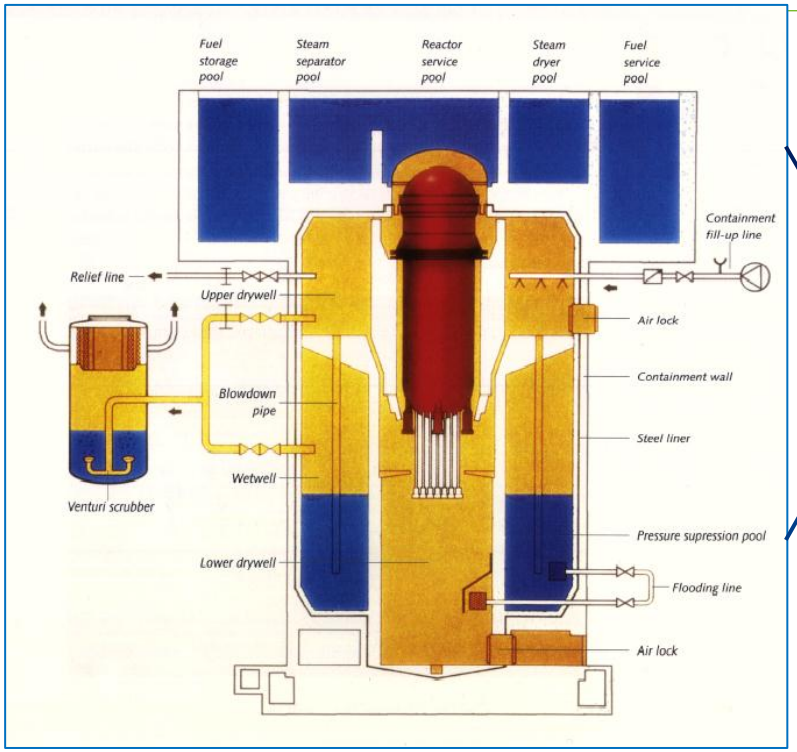
In-vessel retention of corium
- Inlet valves
- Outlet valves
- Lowering of the bottom part of thermal insulation/neutron shield
- Screening of impurities

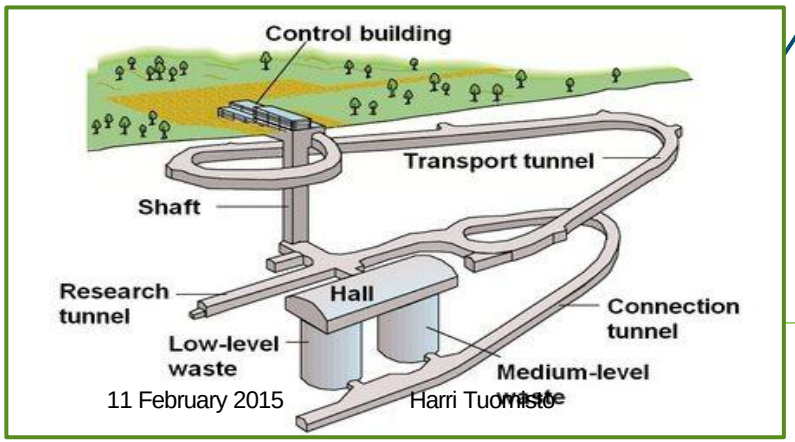




Equipment installed at Loviisa NPP to ensure that IVR System Effects are managed properly or eliminated

Major modifications at Olkiluoto 1 and 2





Modernization and modification projects

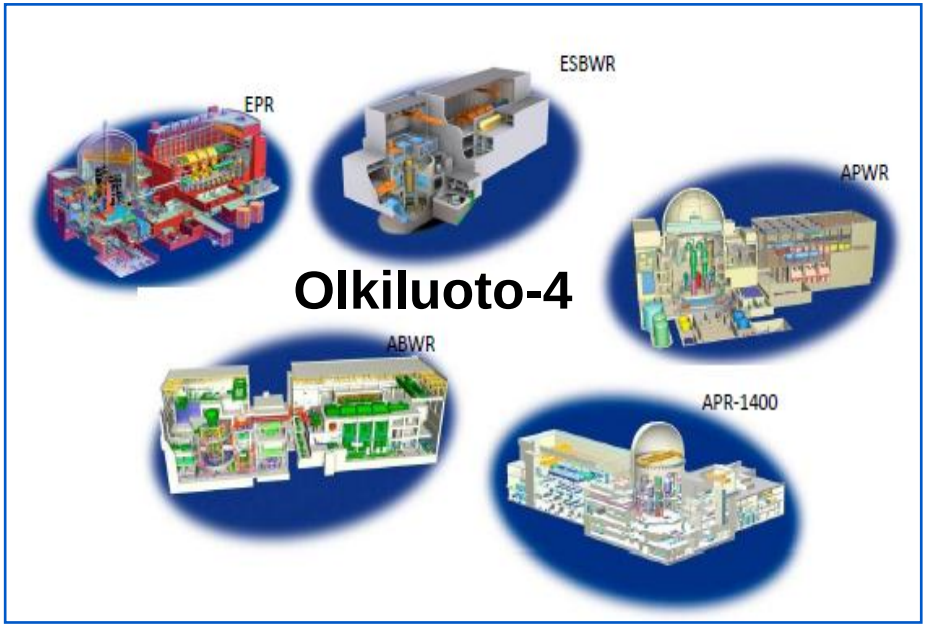
Modernization and reactor uprating, electrical output from 660 MW to 710 MW	1983 – 1984
Construction of interim storage facility for spent fuel (KPA storage)	1984 – 1987
Containment filtered venting system (SAM)	1986 – 1989
Plant-identical training simulator at Olkiluoto 	1988 – 1990
Construction of final repository for low- and intermediate-level radioactive waste (VLJ cave)	1988 – 1992
Modernization programme (MODE) and reactor uprating, electrical output from 710 MW to 840 MW	1995 – 1998
Turbine plant modernization (TIMO), electrical output from 840 MW to 860 MW	2005 – 2006
Low pressure turbines, main generators, sea water pumps etc (PELE), output to 880 MW	**2010 – 2011**

New Build Projects: Plant concepts studied

ABWR AES2006 EPR ESBWR APR1400

Loviisa-3

Hanhikivi-1

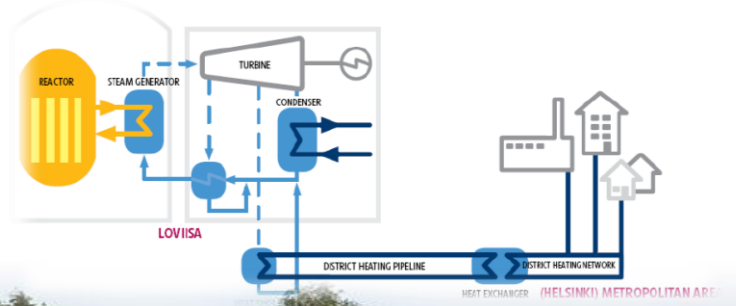


Olkiluoto-4

Olkiluoto 3: EPR

Loviisa 3 CHP option: plans for heat transport to Helsinki

- Replacement of heat generated with fossil fuels in Helsinki region
  - thermal energy consumption (district heat) 11 - 12 TWh per year
- Large reduction of carbon dioxide emissions
  - up to 4 million tons annually (6 % of the entire CO_2 emissions in Finland)
- Higher plant efficiency
  - net electrical power loss approx. 1/6 of the thermal power generated
- Steam extraction from the turbine
  - optimisation, and redesign vs. design of new turbine



Small Modular Reactors

- Fortum has followed actively the SMR development during recent years
- The main drivers behind the interest in SMRs are
  - financing aspects, particularly the investment schedule
  - increasing challenges on the grid stability
    - demands for nuclear to be capable of providing regulating power to compensate increased share of renewables
  - the role of nuclear in the future energy system
  - decreasing the implementation risks of very large projects
  - opportunities to participation of local industries
- Further development needed in legal framework and licensing process to adjust to the introduction of SMRs