Data analysis of the reactor pressure, coolant level and main recirculation flow calibration data and failure events for Olkiluoto 1 and Olkiluoto 2

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Teollisuuden Voima Oy (TVO)

Company

- Privately owned power company in Finland
- Established in 1969
- Personnel about 700
- Annual turnover about million 230 M€
- Sells electricity only to the shareholders at cost basis

Existing NPP Units (Olkiluoto 1 and Olkiluoto 2)

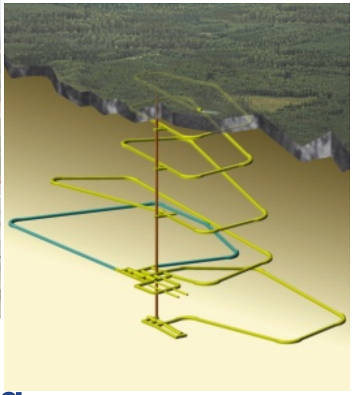
- 2 x 860 MW, BWR, Westinghouse Atom
- Commercial operation 1979 and 1982
- Modernization and upgrade in 1994-1998 and 2005-2006

New NPP Unit (Olkiluoto 3)

- 1 x 1,600 MW, PWR, Framatome-Siemens consortium
- Commercial operation in 2011

Coal Condensing Power Plant Unit (Meri-Pori)

- 257 MW stake in 565 MW coal condensing unit



Subsidiaries

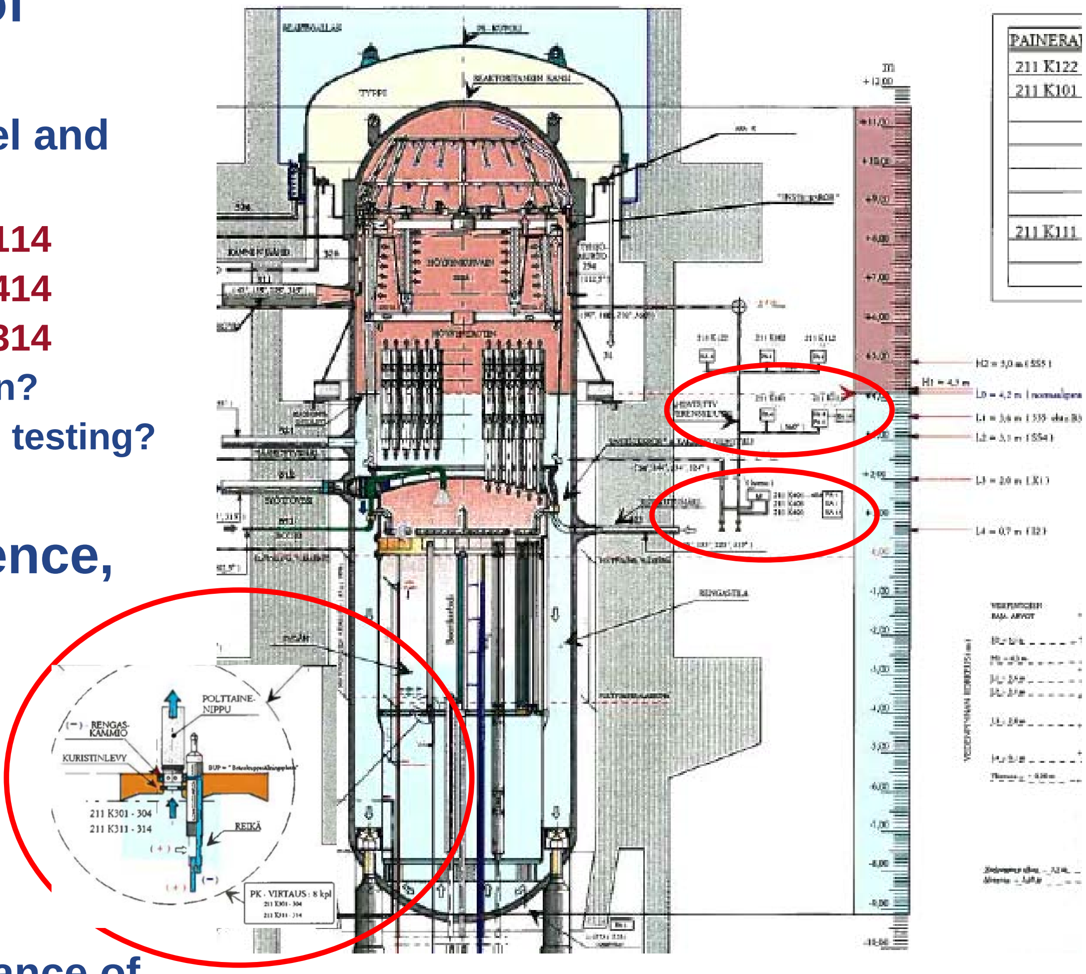
- Posiva Oy (60%), responsible for the final disposal of spent fuel
- TVO Nuclear Services Oy (100 %), specialized in know-how consulting

Introduction

- **Surveillance test evaluation**
  - Internal project – started 2001
  - Tests included in Technical Specifications
  - Limited to tests that are performed during annual outages
  - Risk informed approach
- **Main goals**
  - Possibilities to reduce the effort put on testing activities
  - To study the possible improvement of test procedures
    - Risk reduction possibilities e.g. with alternative test arrangements
- **Organizations involved**
  - Nuclear Safety, Operational Safety, Operation and Maintenance
    - comprehensive aspects from safety, operation and maintenance were gained in the decision-making process

Introduction continues...

- **Case study – calibrations of reactor measurements**
  - reactor pressure, coolant level and main recirculation flow
    - 211K101- K104, 211K111 - K114
    - 211K401- K404, 211K411 - K414
    - 211K301- K304, 211K311 - K314
    - Calibration interval extension?
    - Sequential versus staggered testing?

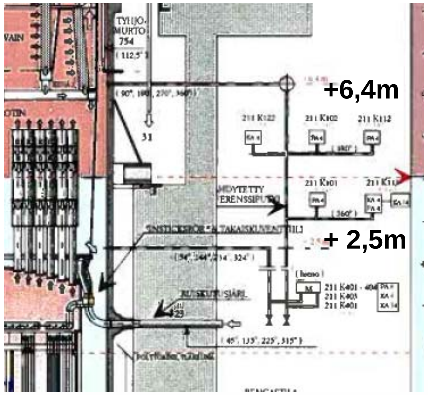


- **OL1/OL2 Operating experience, historical data**
  - Analysis of calibration data
  - Analysis of failure reports
  - Analysis of IE’s (PRA)

- **OL1/OL2 PSA model**
  - Determination of risk significance of calibrations

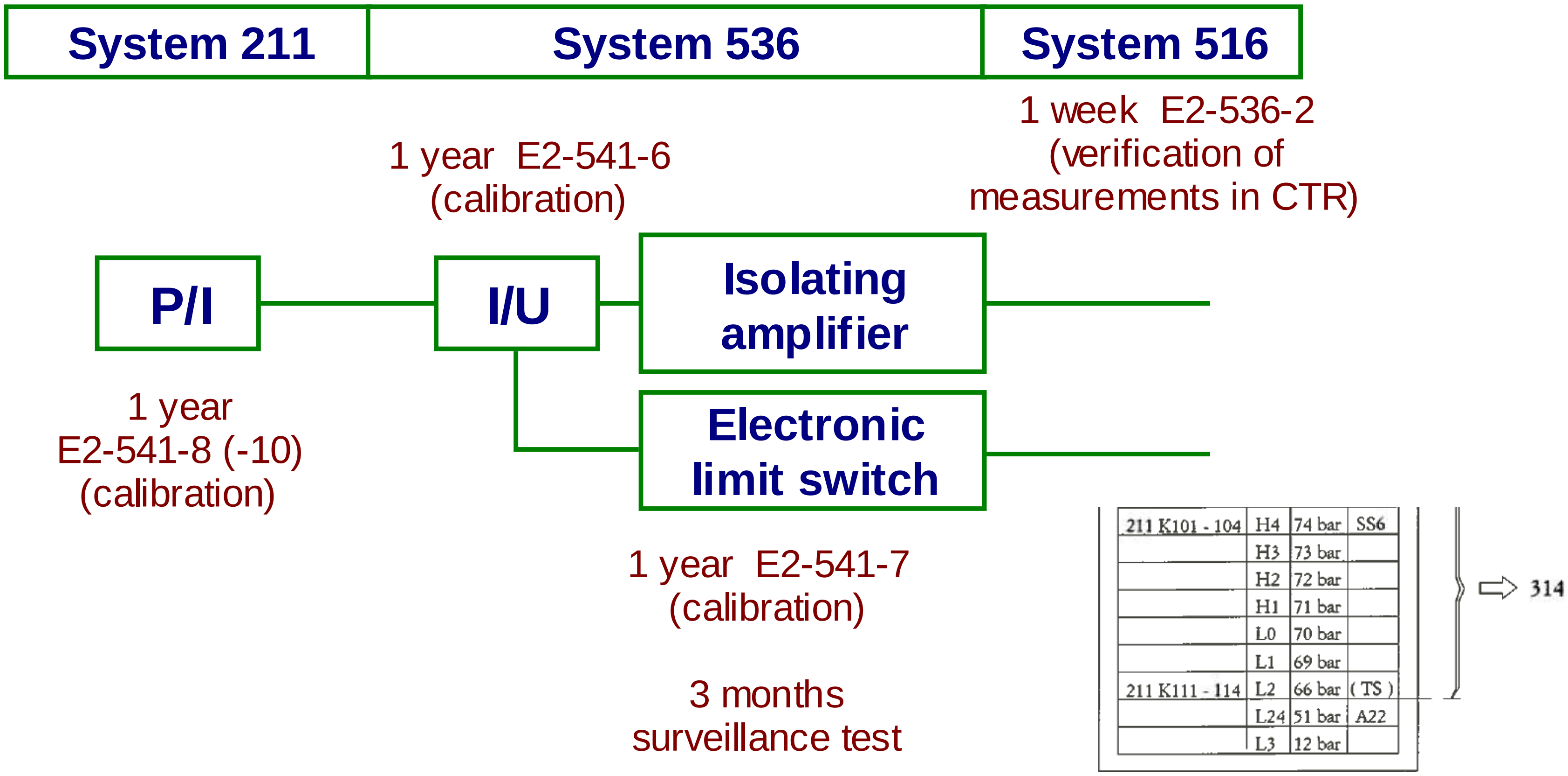
Analysis of the calibration data

- **Source:**
  - Plant specific database for calibration data (EERO)
    - Contains information of all components included in a measurement chain
    - Calibration measurement data
      - Calibration points within measurement range
        - » e.g. fine pressure 60...80 bar, fine level +2,5...+6,4 m
      - Calibration is performed once per year in connection of annual outage



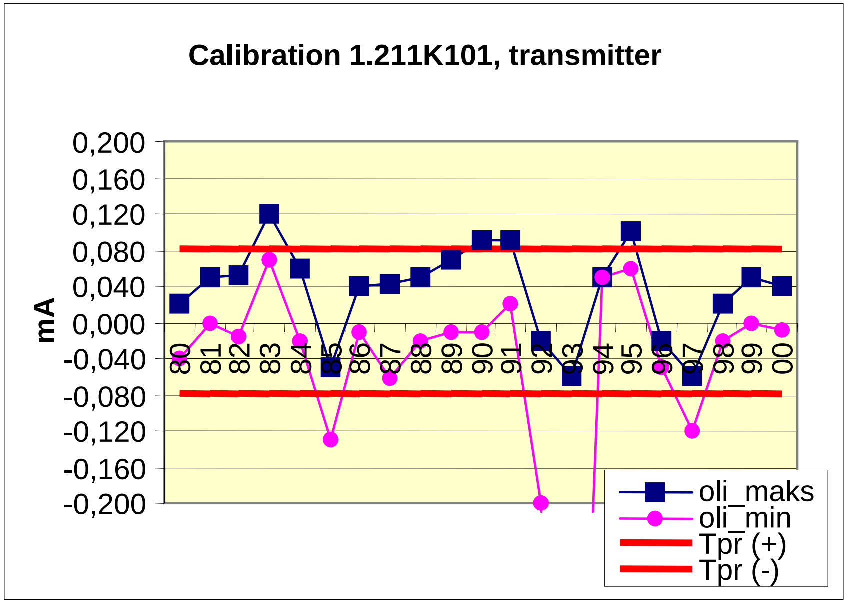
- **Time period:**
  - Calibration data from years 1982-2000

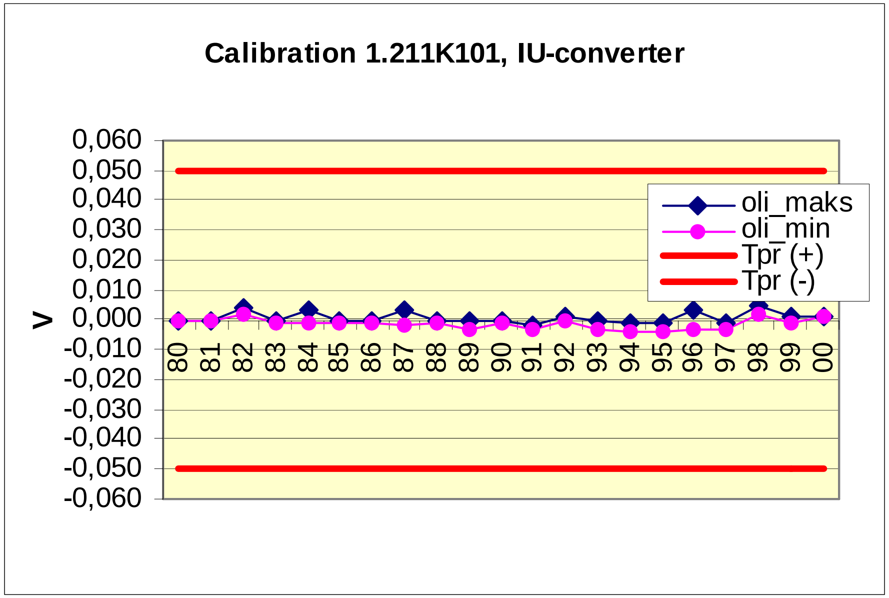
Example of pressure measurement



211 K101 - 104	H4	74 bar	SS6
	H3	73 bar	
	H2	72 bar	
	H1	71 bar	
	L0	70 bar	
	L1	69 bar	
211 K111 - 114	L2	66 bar	(TS)
	L24	51 bar	A22
	L3	12 bar	

Analysis of the calibration data, cont.





Equipment	Action limit
transmitter (level, pressure, flow, temperature)	± 0,08 mA
isolation amplifier	± 50 mV
electronic-limit switch	± 30 mV
IU-converter	± 50 mV
summing amplifier	± 50 mV
majority switch	± 50 mV

Analysis of the calibration data, cont.

OL2, Pressure measurement Calibrations (1986-2000)	Frequency of exceeding the action limit (1/year)
Transmitters (F) Transmitters (C)	0,48 0,03
Transmitters (F&C)	0,26
IU conv.,, QAIC	0,007
UU conv., QAGO	0,002
Electronic limit switch (F) Electronic limit switch (C)	0,035 0,029

Analysis of failure events

- Plant specific maintenance database as source
  - “TTJ” (former ATV)
    - Analysis of failure events reported
    - Covers time period 1983-2001
    - Critical failures and their failure modes in measurement chains
  - Simplified approach was applied
    - criticality classification
      - critical, repair critical, non critical
    - failure mode for critical failures
      - according to coding and description in the failure report
      - e.g. “spurious output” or “no output”

Analysis of failure reports, cont.

Failure reports 83-01

Reactor Pressure

OL1	**tot**	**Cri**	**Rcri**	**N**
211K101-K104	2			2
211K111-K114	4		1	3
Total OL1	**6**	**0**	**1**	**5**

OL2	**tot**	**Cri**	**Rcri**	**N**
211K101-K104	4		3	1
211K111-K114	2			2
Total OL2	**6**	**0**	**3**	**3**

Fine pressure OL1/OL2	6	0	3	3
Coarse Pressure OL1/OL2	6	0	1	5

Total OL1/OL2	**12**	**0**	**4**	**8**

12 failures are reported

- *no critical failures*

Reactor level

OL1	**tot**	**Cri**	**Rcri**	**N**
211K401-K404	8	1	3	4
211K411-K414	8	1	3	4
Total OL1	**16**	**2**	**6**	**8**

OL2	**tot**	**Cri**	**Rcri**	**N**
211K401-K404	10	4	3	3
211K411-K414	16	4	9	3
Total OL2	**26**	**8**	**12**	**6**

Fine Level OL1/OL2 yht.	**18**	**5**	**6**	**7**
Coarse Level OL1/OL2 yht.	**24**	**5**	**12**	**7**

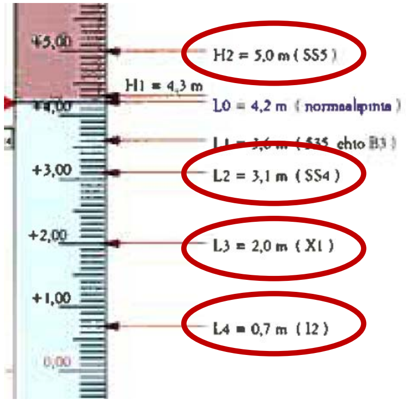
Total OL1/OL2	**42**	**10**	**18**	**14**

42 failure reported - 10 critical failures

- *7 cases – no output*
  - *transmitter failures*
- *1 human error*
  - *maintenance and restoration of measurement channel*
- *2 spurious*
  - *inadvertent trip of one channel*

Analysis with OL1/OL2 PRA model

- **Modelling in OL1/OL2 PRA**
  - **Component boundary - components from transducer up to the electronic limit switch in each measurement channel**
    - **Reactor pressure**
      - **211K101 – 211K104 – P/I low signal**
      - **211K111 – 211K114 – P/I high signal**
    - **Reactor level**
      - **211K401 – 211K404 – DP/I high signal**
      - **211K411 – 211K413 – DP/I high signal**
    - **Reactor flow**
      - **211K301-K304, K311-K314 – not modelled (MC- flow signal)**
  - **Electronic limit switches – different actuation set-points**
    - **Level - limit values H2, L2, L3, L4**
    - **Pressure, limit values H4 and L3**
      - **Impulse lines & 516-logic is modelled, but not considered in this analysis**



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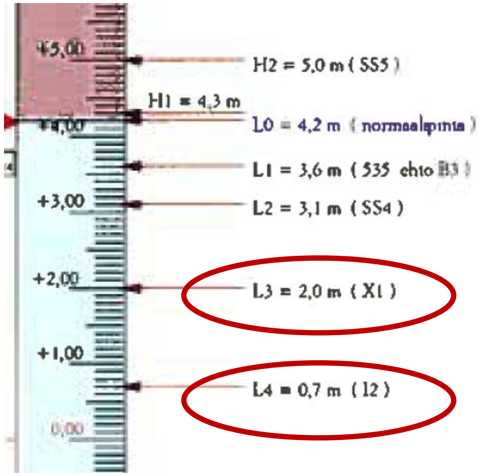
Analysis with OL1/OL2 PRA model, cont.

- Initiating event for OL1/OL2 units (1983-2001)
  - No plant disturbance has been occurred due to reactor pressure, reactor level or reactor flow measurements
- In connection of RPS (516) system analysis in PRA
  - Multiple human errors related to calibration treated as “CCFs”
    - Significant contributor to CDF

- Modeling of multiple human error in X1/I2 calibration
  - Low level in reactor pressure vessel (X1:L3=2,0m / I2:L4=0,7m)
    - Most important “multiple human error” - probability is estimated to be rather low $2 \cdot 10^{-5}$
    - Already reduced some years ago after the test procedure changes



Analysis with OL1/OL2 PRA, cont.

- PRA model (Rev. 334)
  - Reactor pressure and level measurement
    - contribution to the core damage frequency without considering system 516 and impulse lines in system 211
      - ~ $2{,}6 \cdot 10^{-6}$ 1/ra thus 13 % of total CDF (~$2 \cdot 10^{-5}$ 1/year)
  - The most important contributors
    - human errors, especially multiple errors in calibration (CCF)
      - Fussel-Vesely importance measure is 13%
      - Risk increase factor 650
      - most important – RPS conditions I2/X1 of reactor level measurement

Results and conclusions

- In past sequential calibrations have been performed annually during the outages (four-fold trains A, B, C and D)
- Based on the study the calibration interval could be extended according to calibration data and failure data analysis with exception
  - Flow measurement
    - the calibration interval could be longer, but due to operational reasons the calibration is needed every outage after refueling – thus no change proposed
- According to PRA study the core damage risk can be reduced significantly
  - if the calibrations are staggered in train pairs
    - the threefold and quadruple calibration errors can be eliminated practically
    - ☞ trains A and C will be calibrated every second year and trains B and D correspondingly

Results and conclusions, cont.

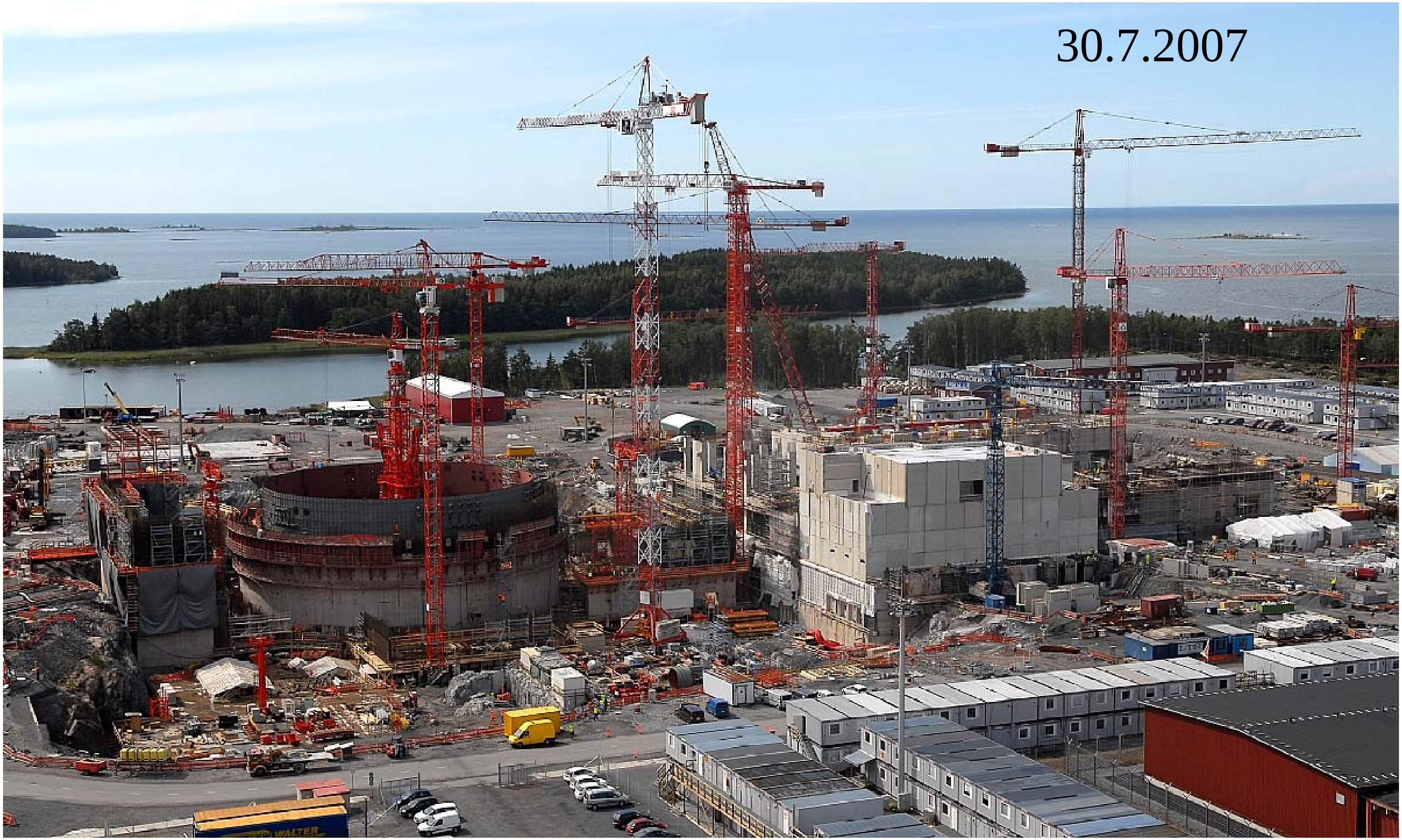
- Technical Specification change application was sent to STUK
  - change in reactor and pressure level measurements
    - consisted on the proposal of staggering the calibration activity
- STUK accepted this proposal at the end of the year 2005
  - effective during the outages 2006


27.5.2003


4.10.2004


25.8.2005


1.3.2006


30.7.2007
WALTER


May 2008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May 2008

Thank you!