Development and Implementation of Safety Upgrades for VVER Reactors in Support to Long Term Operation

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we advance technology
& services to power a
clean, carbon-free future.

- Customer Focus & Innovation
- Speed & Passion to Win
- Teamwork & Accountability

Safety • Quality • Integrity • Trust

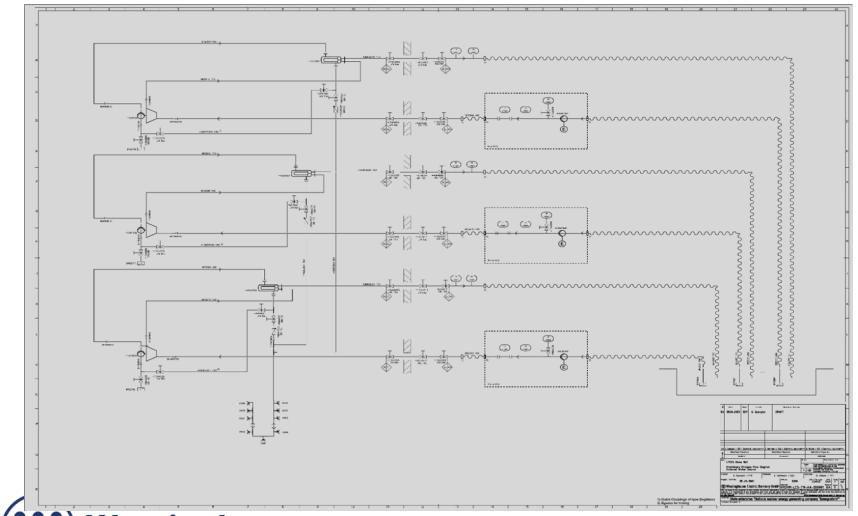
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Westinghouse VVER Engineering Projects and Developments

- SUNPP Units 1&2 (VVER-1000) – Implementation of DFM
- Temelin NPP Units 1&2 (VVER-1000) – Implementation of DFM
- Rivne NPP Units 1&2 (VVER-440) – Implementation of Long Term Containment Cooling System
- Hanhikivi 1 – Containment Design Review
- Risk Informed Applications for VVER









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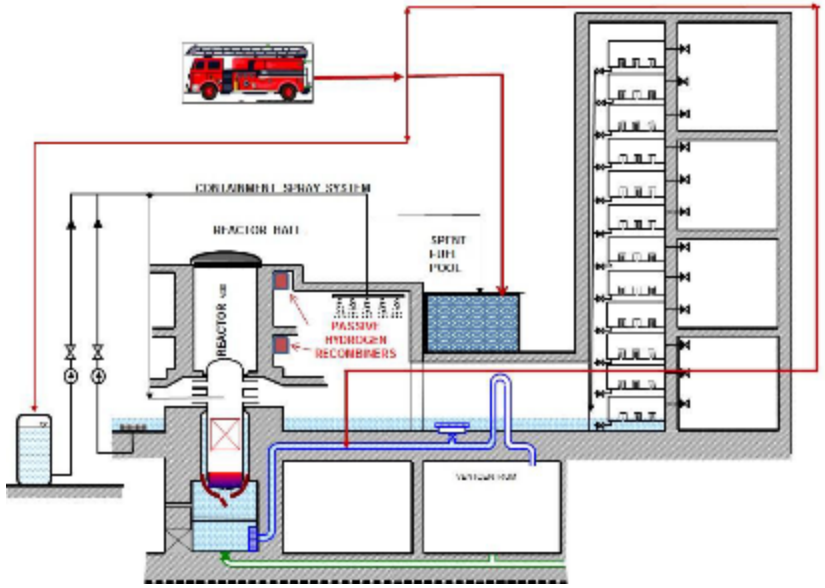
Licensing Environment for Implementation of Safety Upgrades

- Safety upgrades are driven by regulatory requirements as national action plans after the Fukushima accident, international task force review findings and LTO.
- Different regulatory bodies – not a unified framework for plant modifications.
- Additional effort to work with the utility is required in order to obtain a pre-approval for a FOAK project
- Required are usually:
  - Design validation
  - Preliminary safety analysis report
  - Technical specifications document
- Equipment qualification – accident conditions;
- The standards that are applicable for equipment and calculations performed by cross-border suppliers need to be set and agreed in advance.

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Development of Long-Term Containment Cooling System

- IVMR strategy is implemented in most of the VVER-440/V-213 plants;
- Flooding the reactor cavity and submerging the RPV;
- Passive natural circulation and removing the heat from the RPV walls;
- Vaporization of the coolant in the cavity will increase the steam content, resulting in a pressure build-up;
- Long term pressurization can challenge the containment integrity and result in radioactive releases.
- After certain period of time a solution for containment cooling is needed.
- Long term containment cooling solution is under implementation in most VVER-440 in Europe.

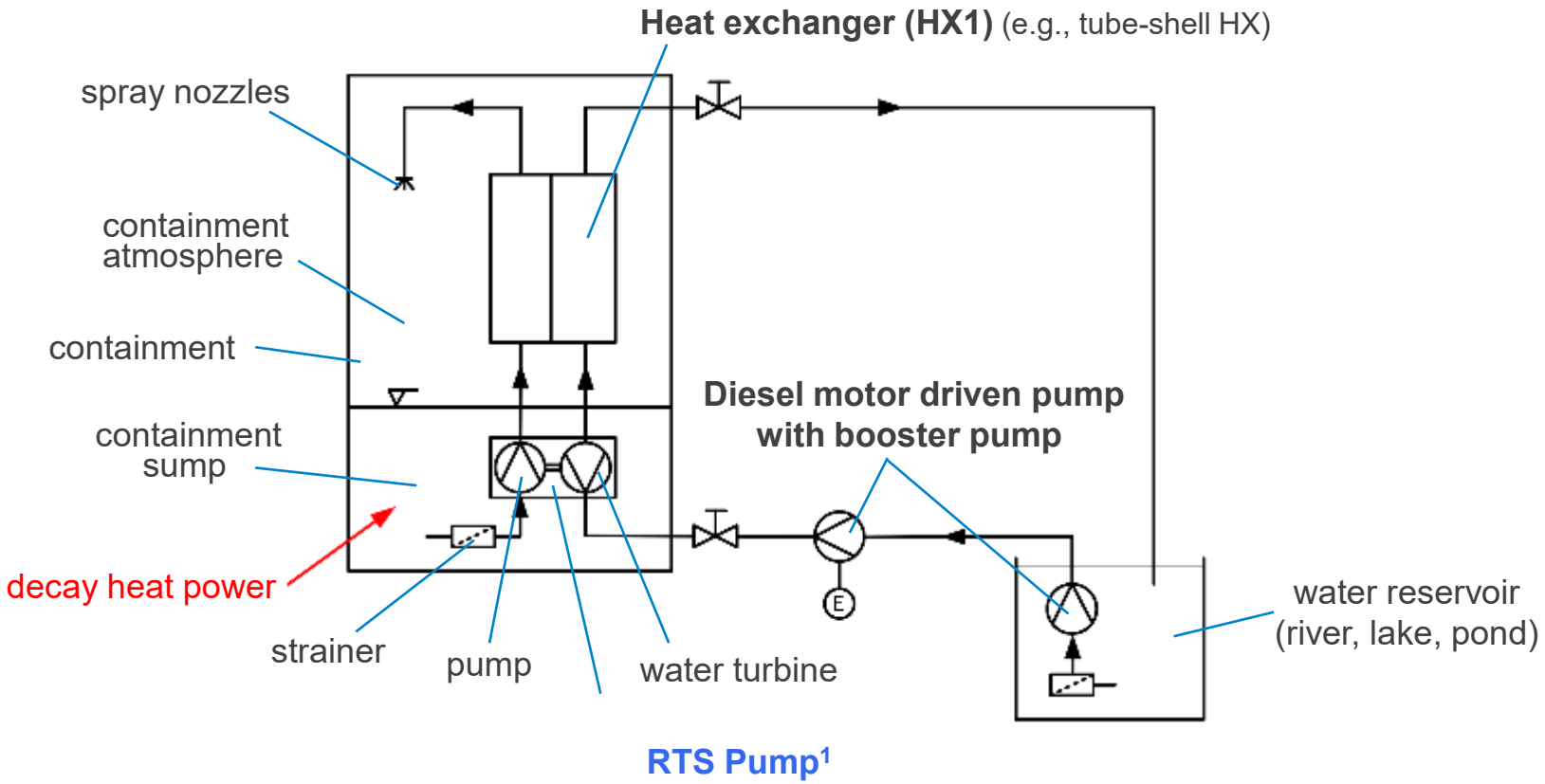


Source: National Report on The Stress Tests for Nuclear Power Plants in Slovakia, 2011.

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LCCS Layout: Connection to External Water Source

- Three independent trays based on Client requirement.
- Each **RTS Pump[1]** is connected to a separate heat exchanger.
- RTS Pumps are in a compartment under the reactor cavity.

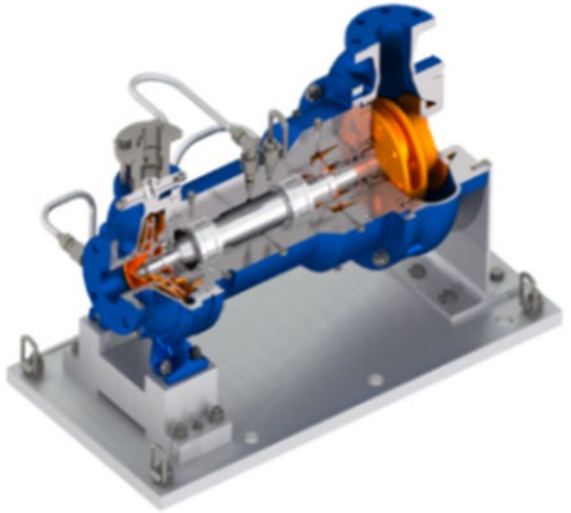


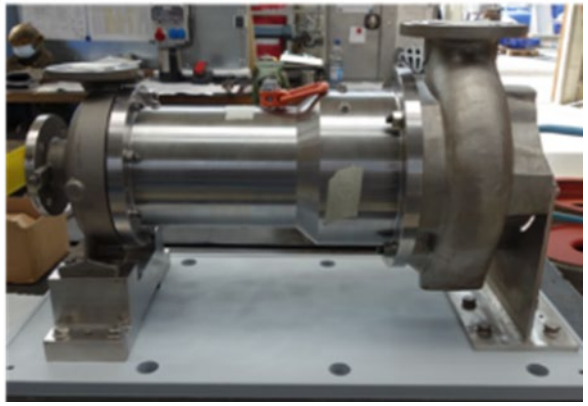
[1]RTS Pump is trademark of KSB GmbH

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RTS Pump Qualification

- Test program for qualification of the **RTS Pump** under accident conditions defined and developed based on:
- KSB **RTS Pump** prototype tested at KSB Facilities in the following sequence:
  - **Hydraulic Performance Test (HPT)**
  - **Visual Inspection Test (VIT)**
    RTS Pump prototype dismantled for visual inspection of all relevant parts
  - **Harsh Environment Test (HET)**
    Testing the **RTS Pump** prototype operation under similar to the expected accident conditions (on a specially designed and developed facility)
  - **Second Round of HPT and VIT**
    Verifying the condition and performance of the **RTS Pump** prototype after the HET
  - **Leak Tightness Test**
    Hydrostatic tests for leakage of mechanical seal, and pump + turbine housings

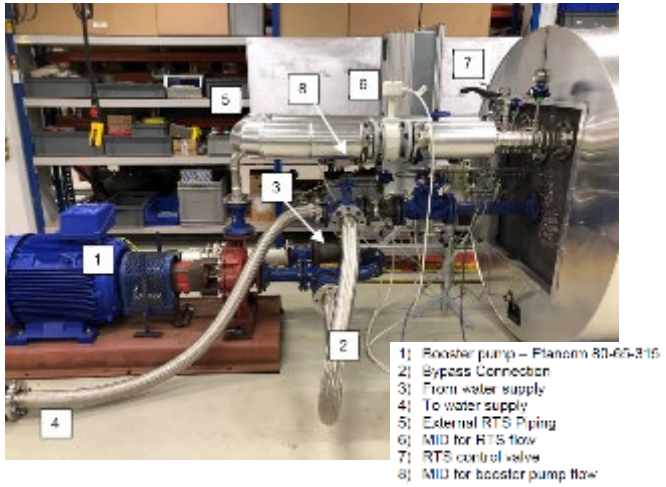


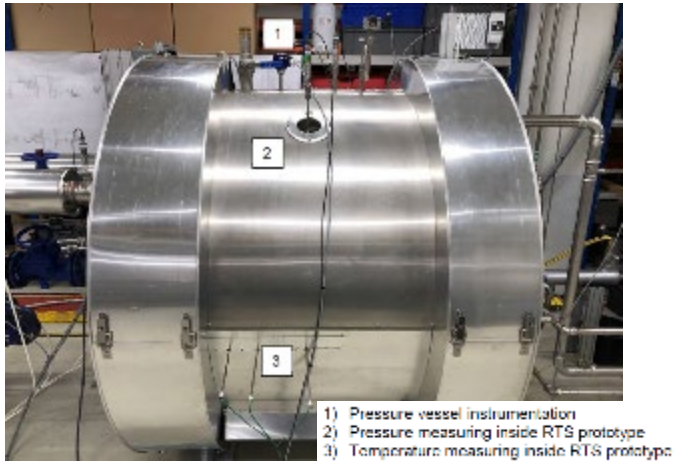


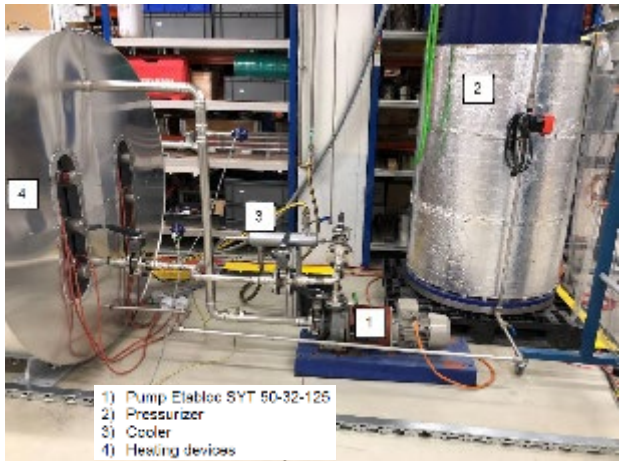
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RTS Pump Qualification – Harsh Environment Tests

- To ensure proper operation of the **RTS Pump**:
  - Under harsh environment conditions, similar to the expected severe accident conditions, as defined analytically;
  - With debris loaded water;
  - High temperature and pressure peaks on the pump side;
  - Operation of 35 days being representative for long term operation.
- To simulate these conditions, a test bed was developed and built up at KSB.
- **RTS Pump** is placed inside a flooded and isolated pressure vessel which recreates a pump under submerged conditions:
  - The water temperature inside the vessel is controlled by electrical heating devices and an external recirculation pump plus heat exchanger cooler unit, also avoiding thermal stratification inside the vessel. Pressure inside the vessel is controlled via a pressurizer connected to a compressed air system and solenoid valves.
- The HET were performed between Feb-15 and Mar-23, 2021.







KSB Test Facility for HET of RTS Pump

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Project Status: Equipment Delivery

- System deign, equipment delivery and overall integration – Westinghouse:
  - Detailed system design and manufacturing (HXs, piping, valves, external pumps, etc.) – ES Group (Czech Republic);
  - RTS Pump Manufacturing – KSB GmbH (Germany);
  - Manufacturing of Passive Autocatalytic Recombiners – NIS (Germany).
- Currently all equipment is manufactured, tested and delivered.
- Rivne NPP Unit 1 & 2 – Installation preparation activities
- Next steps:
  - Installation and pilot operation.









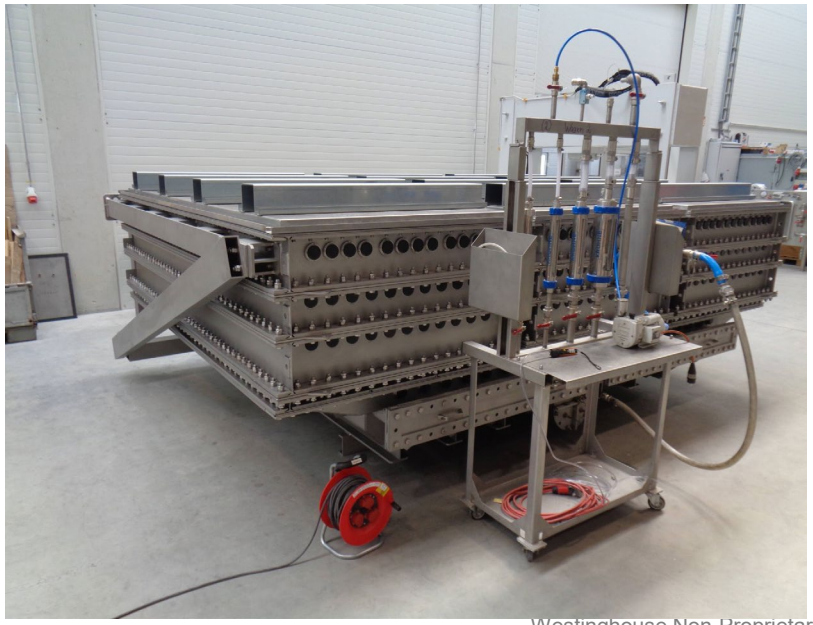
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Temelin DFM Project

- Client – CEZ Energoservis;
- Filter manufacturer – Krantz GmbH
- Project Initiated in 2021
- Design documents – February, 2022
- Installation – 2024 for both units







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Filter Sizing – DFM 2.0 is Recommended Technology

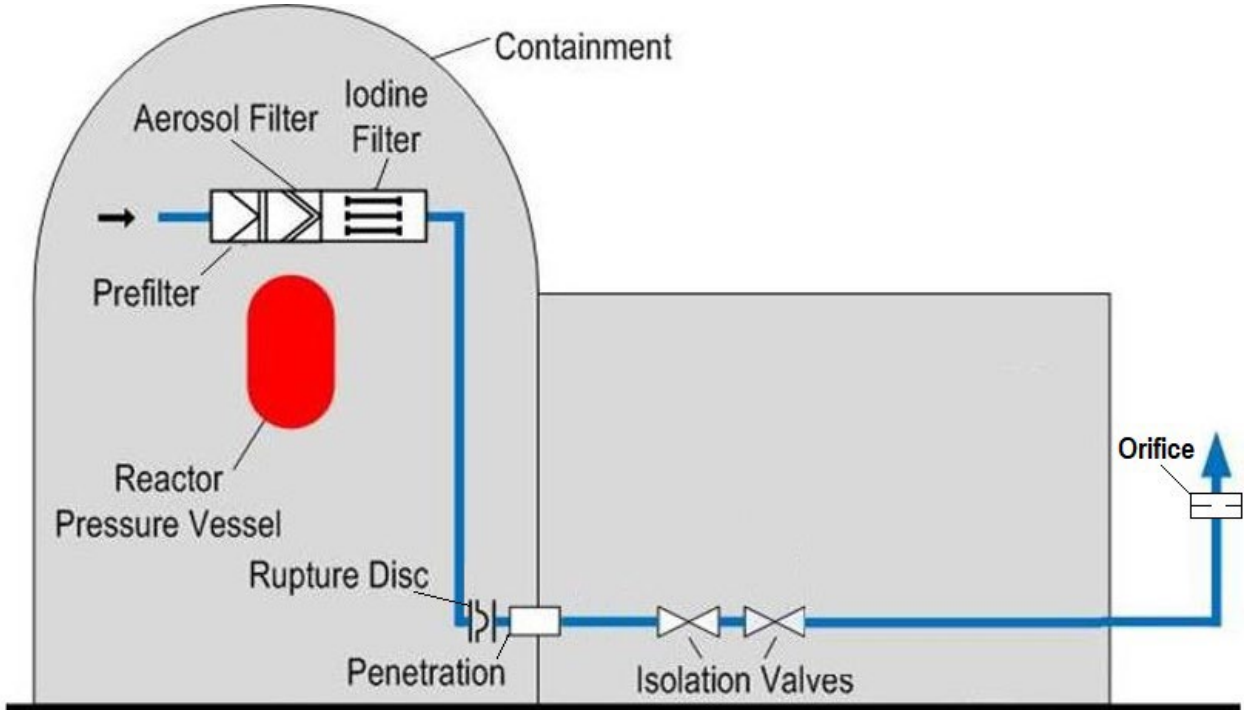
Main Data Related to Filter Housing

Parameter	Comment
Type of filter housing	Double-sided in-containment combined aerosol iodine filter (DFM 2.0)
Number of filter housings	1 per Unit
Number of filter units	4 (3 aerosol filter units and 1 iodine filter unit in each housing)
Length of single filter housing	approx. 4.27 m
Width of single filter housing	approx. 1.42 m
Height of single filter housing	approx. 2.98 m
Weight of single filter housing (filled)	approx. 10.000 kg

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Temelin DFM Project

- The first opening of the CFVS will be considered during pressure in the containment equal to the pressure value of 0.69 MPa (abs)
- The mass flow rate of all gases through the CFVS is 7.5 kg/s at pressure of 0.5 MPa (abs) in the containment
- The first closure at a pressure of 0.4 MPa (abs) and the second permanent opening at a pressure of 0.5 MPa (abs)
- Mass of retained aerosols ~ 10 kg
- Containment temperature ≤ 170C.



Illustrative sketch of DFM 2.0 based venting system with combined aerosol/iodine filter inside containment

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Risk Informed Applications for VVER

- Risk-Informed operation at Nuclear Power Plants have been successfully implemented around the World and resulted in significant savings measured in:
  - Operating flexibility (i.e., reduced plant shutdown resulting from systems availability)
  - Outage length reduction due to on-line maintenance and test interval optimization
  - Dose budget saving due to optimized in-service inspection.
- Risk-Informed operation is not only periodically aiming at risk metrics reduction but is mainly managing risk
- PRA used for baseline CDF reduction are not detailed enough to fully capture risk evolution at site
  - Low risk contributors for based case may be screened out from models, which reduces the resolution capability of models to address configuration changes during operational evolution.
  - Day to day PRA usage makes them refined enough to realistically address configurations evolutions and changes.
- Westinghouse has International experience and expertise that can be easily applied to RI applications in VVER reactors

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Risk Informed Applications for VVER

- Main Objective: Regulatory Confidence in PRAs
  - In US, NRC is so confident in the PRA technical adequacy that they are themselves proposing RI applications (e.g., RIPE)… this took a long time to get.
  - Regulatory acceptance of risk-Informed applications still limited in many Countries, where PRAs are used only as a regulatory tool rather than tools for improving operation.
- Roadmap for gaining Regulatory Confidence
  - Confidence in PRA being increased by independent peer reviews and compliance with International Standards (e.g., IAEA-SSG 3-4, ANS/SME PRA Standards)
  - Importance of a solid PRA Configuration Control Program that supports the WENRA concept of living PSA (a peer reviewed PRA is instantaneously outdated without a PRA Configuration Control Program)
  - Piloting of small RI initiative (e.g., single surveillance test extensions, single AOT extensions) is recommended rather than ambitiously aiming at the US-style RI industry initiatives such as Utility controlled surveillance Test Frequency Control Program, Risk Informed Completion Times, 50.69)

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