AREVA's Solutions for Post-Fukushima Safety Enhancements

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Moscow, 4 June 2012

International Forum ATOMEXPO-2012
“Nuclear Power after Fukushima in Operators’ Eyes”

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AREVA's Solutions
Extension of the Grace Period

- Assessment of plant's robustness against hazards
- Full new diverse heat sink (scope: Design Basis Accident)
- Bunkered emergency supply building
- Hardening the secondary "Bleed & Feed"
- Inspirations from AREVA's new NPPs
- Mobile solutions for further risk mitigation

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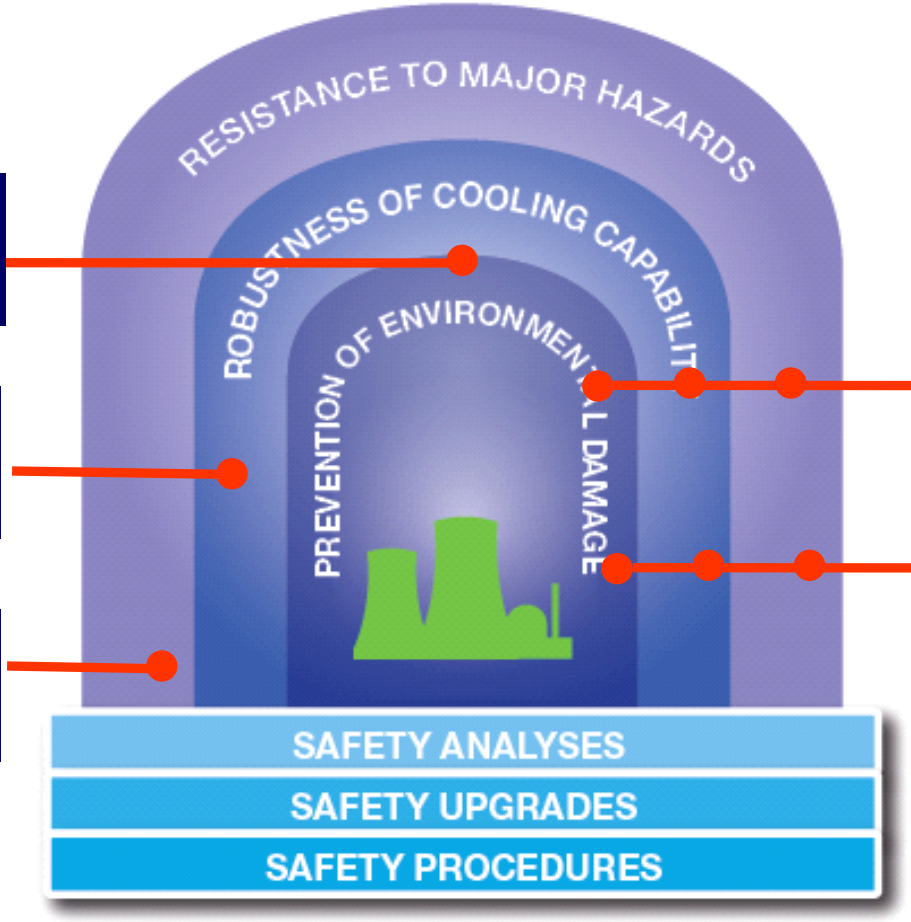
The 6 Main Safety Topics



3 Release Prevention

2 Robustness of the Cooling Function

1 Safety Margin Reassessment

4 Robustness of Monitoring and Control

5 Safety Procedures and Emergency Support

6 Safe Used Fuel Management

Station Blackout and Loss of Ultimate Heat Sink Regulatory Trends

- **More challenging requirements on extended grace periods are expected worldwide, e.g.:**
  - **the 7d/3d German approach for maintaining the residual heat removal and barrier's integrity under "Station Blackout" and "Loss of Ultimate Heat Sink".**
  - **3d plant cooling autarky without support from outside and time critical accident management measures.**
  - **The safety functions should be maintained until recovery of a plant-grid connection, but not less than 7d.**
    - After 3d credit can be taken from well prepared and reliable available external support.

Robustness of the Plant against Beyond Design Hazards

Plant Specific Assessment

Which essential functions are required to prevent core damage, large or early releases?

Grace Period

How much residual heat has to be removed at what time to have the necessary essential functions available on time?

Robustness

Cliff edge effects

Which practically not eliminable“ Beyond Design Basis external or internal hazards could lead to loss of heat sink or water supply? (Failure ranking considering the level of robustness or prevention)

Plant Autonomy

Information Blackout

Which requirements should the AM measures fulfill to compensate the loss of the designed heat sink and heat removal systems?

Accessibility

Connectability

How such AM measures can be realized?
Which level of robustness is achievable?

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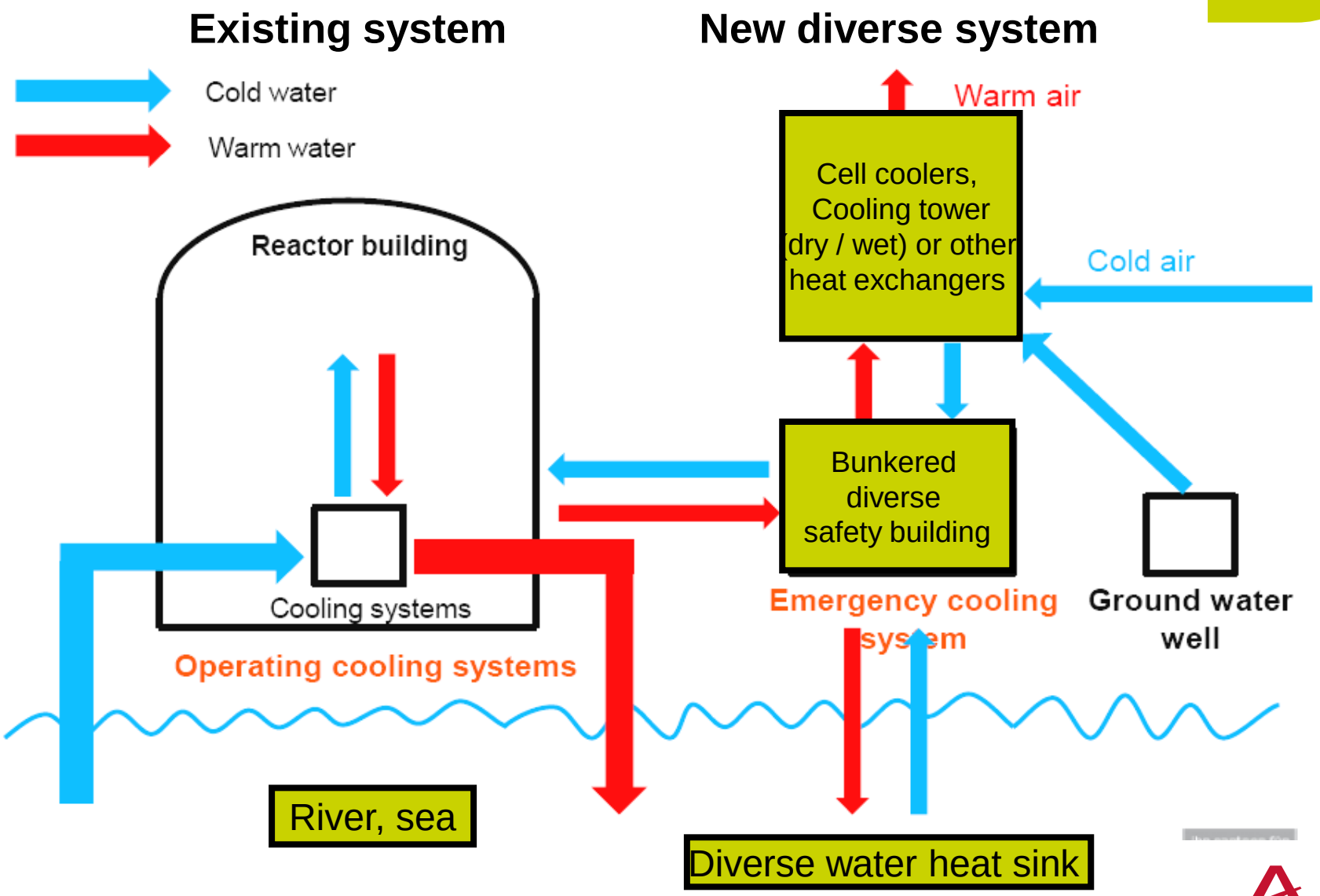
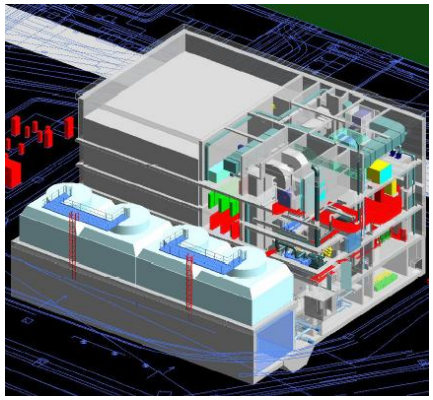
Alternate Ultimate Heat Sink Solutions Embedded in the Plant Cooling Systems



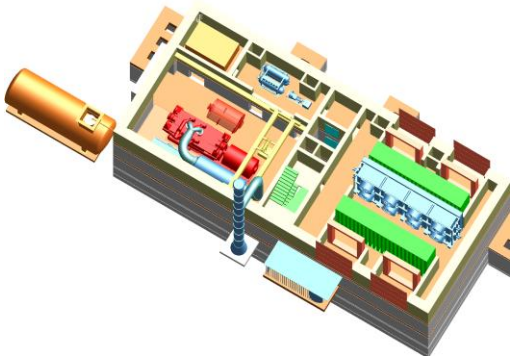
Emergency Power Supply
AREVA Projects

NPP Upgrade, Sweden
2 Buildings with 2 DGs each
-> 1 Building approx. 12,000 m³



NPP Upgrade, Germany (1)
1 Building with 2 DGs
+ Air Cooling system,
Building approx. 21,000 m³

New Build – per EPR:
2 Buildings, each with
2 EDGs + 1 SBO-DG



NPP Upgrade, Germany (2)
1 Building with 1 DG,
Building approx. 11,000 m³

NPP Upgrade, Switzerland
(project prepared)
2 Buildings with 2 DGs each
-> 1 Building approx. 10,000 m³

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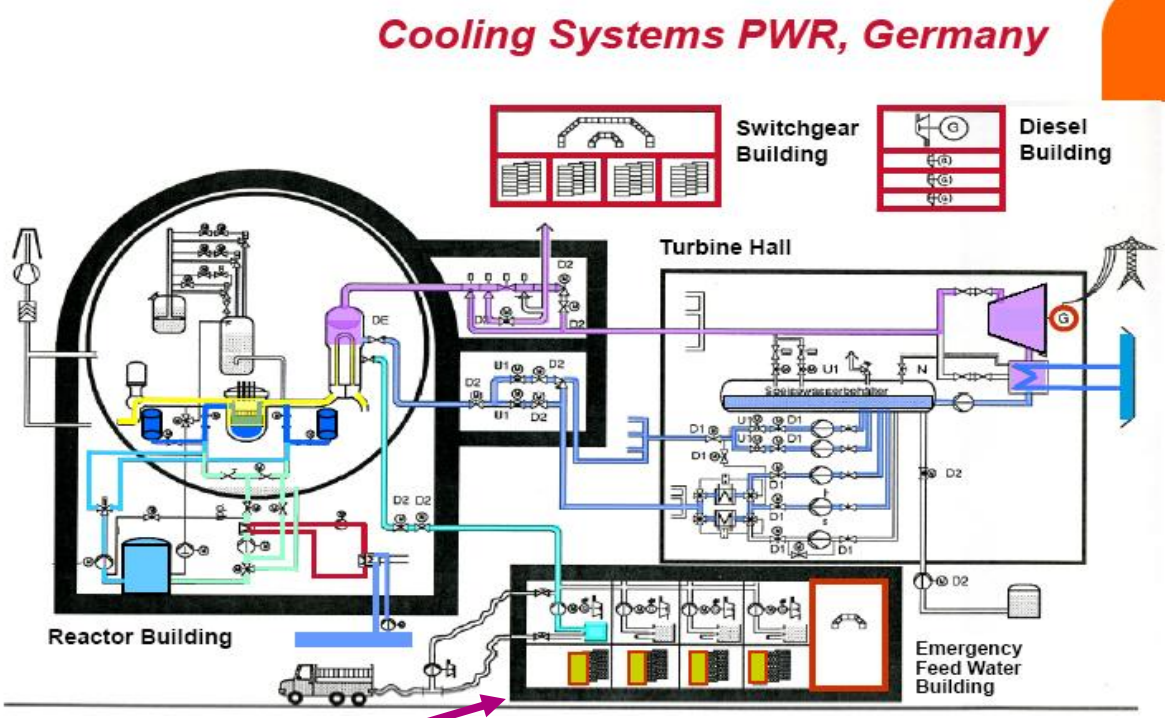
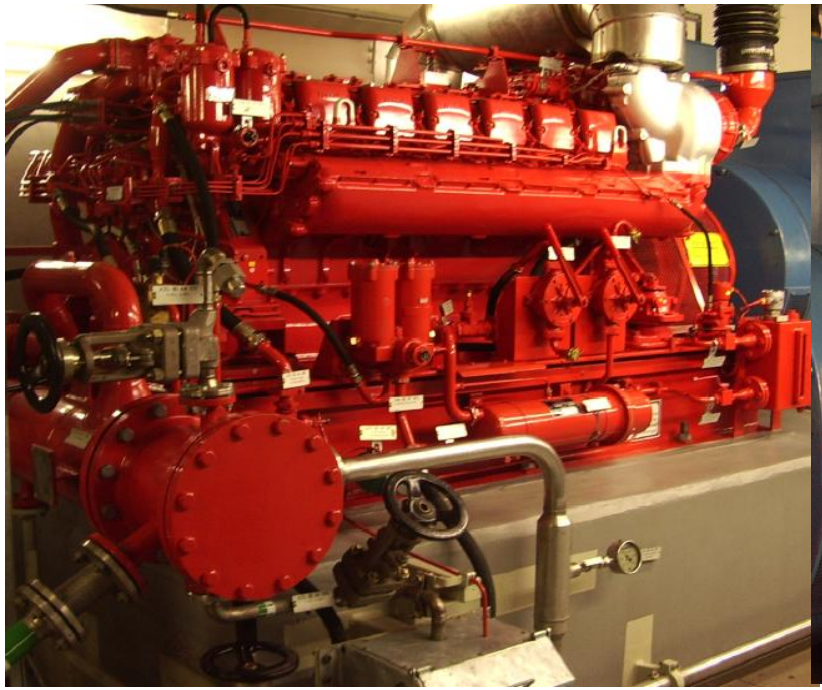
Diverse Heat Sink Solutions – Bleed into Atmosphere Hardening the Secondary "Bleed and Feed" (1/2)

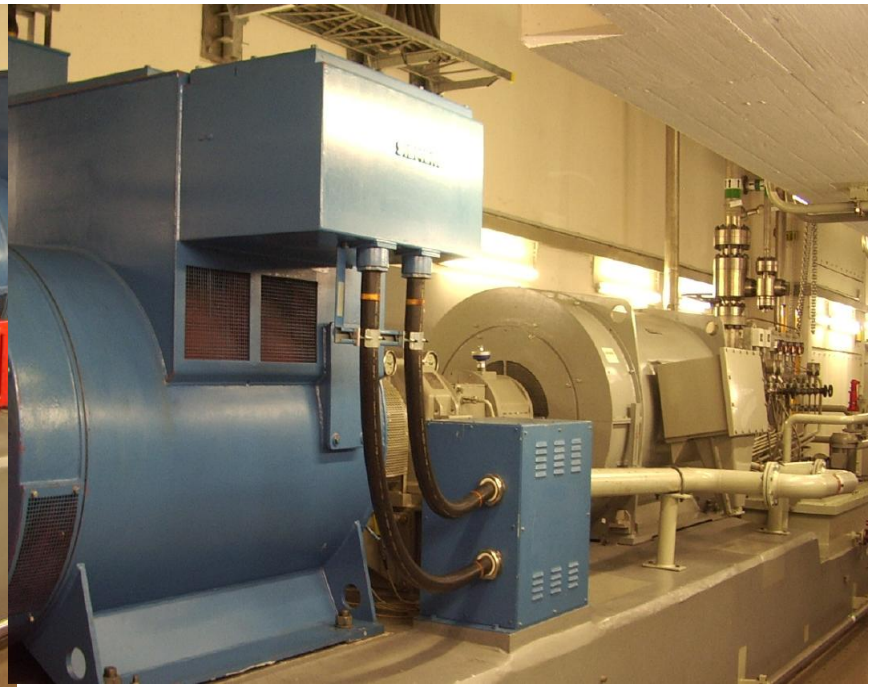
- **Example: (Pre-) Konvoi 3d extension of plant's cooling autarky by use of the bunkered emergency feedwater and diverse power supply building**



Diverse Heat Sink Solutions - Bleed into Atmosphere Hardening the Secondary "Bleed and Feed" (2/2)

- **Open cooling into the atmosphere by "Secondary Bleed&Feed"**
  - **Demonstrated for German NPPs by calculation (72h autarky with the bunkered EFW-DG D2-system)**
- **Open Reactor and Spent Fuel Pool**
  - **Shortened primary cooling chain supplied by AM measures**
    - Cooling water from outside water reservoirs
  - **Spent Fuel Pool cooling under SBO**
    - Bleed into the containment
    - Feed among others by a separate pipe directly into the pool from above





On one axle: Diesel – Generator – Motor alternate to the Diesel - EFW Pump

Mobile Solutions for further Risk Mitigation

AREVA's investigations on behalf of and in cooperation with E.ON

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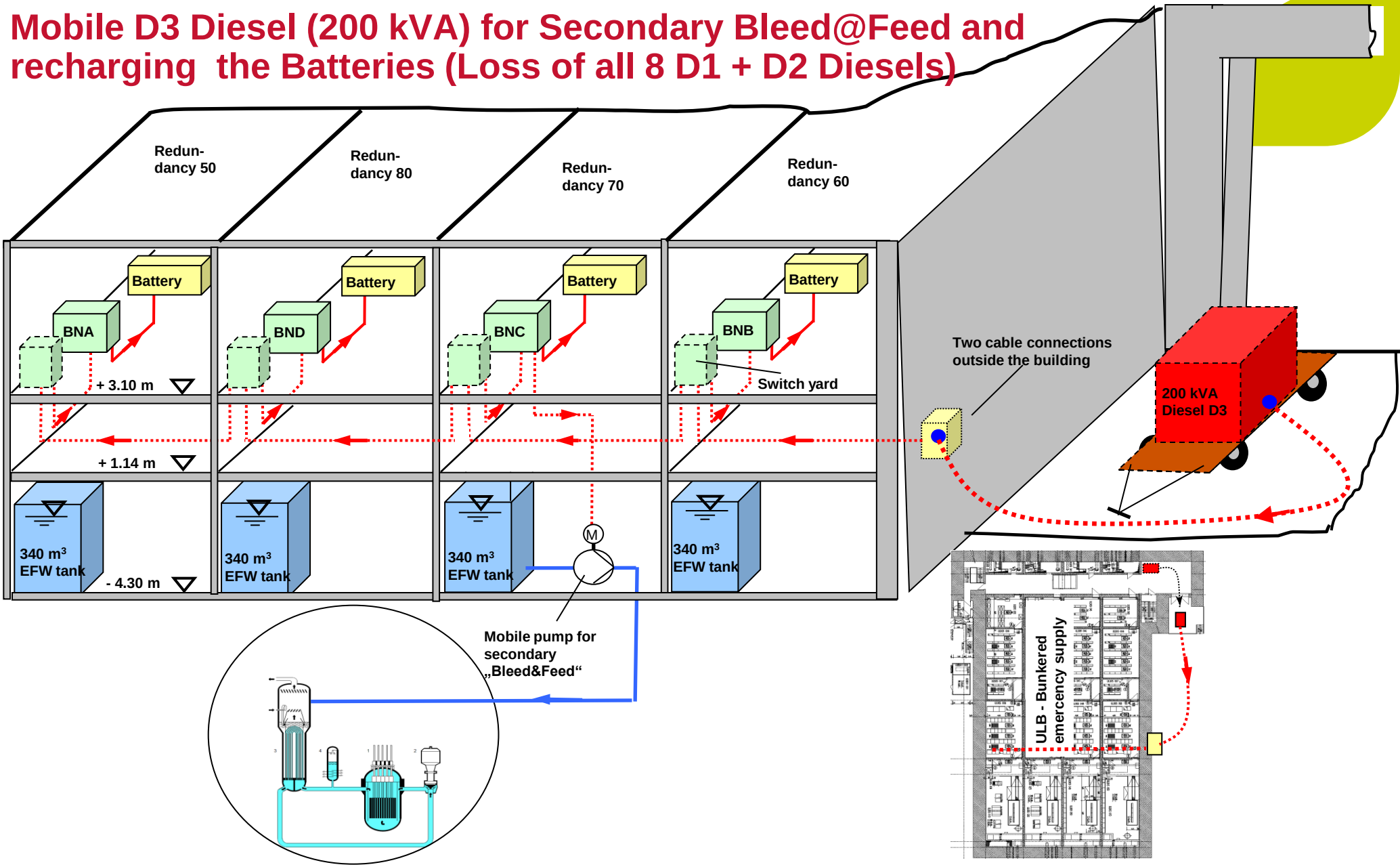
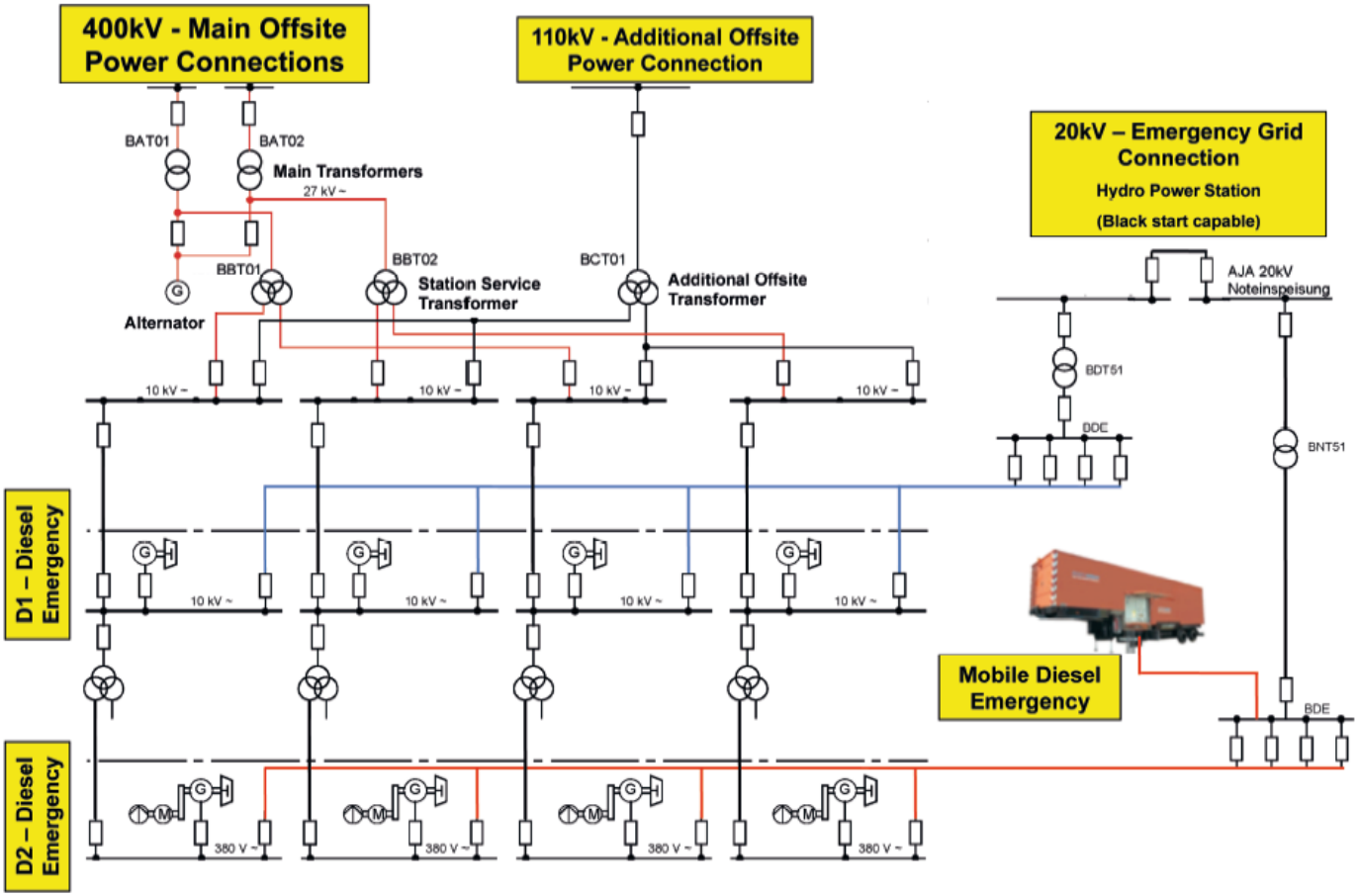
Mobile D3 Diesel (200 kVA) for Secondary Bleed@Feed and recharging the Batteries (Loss of all 8 D1 + D2 Diesels)



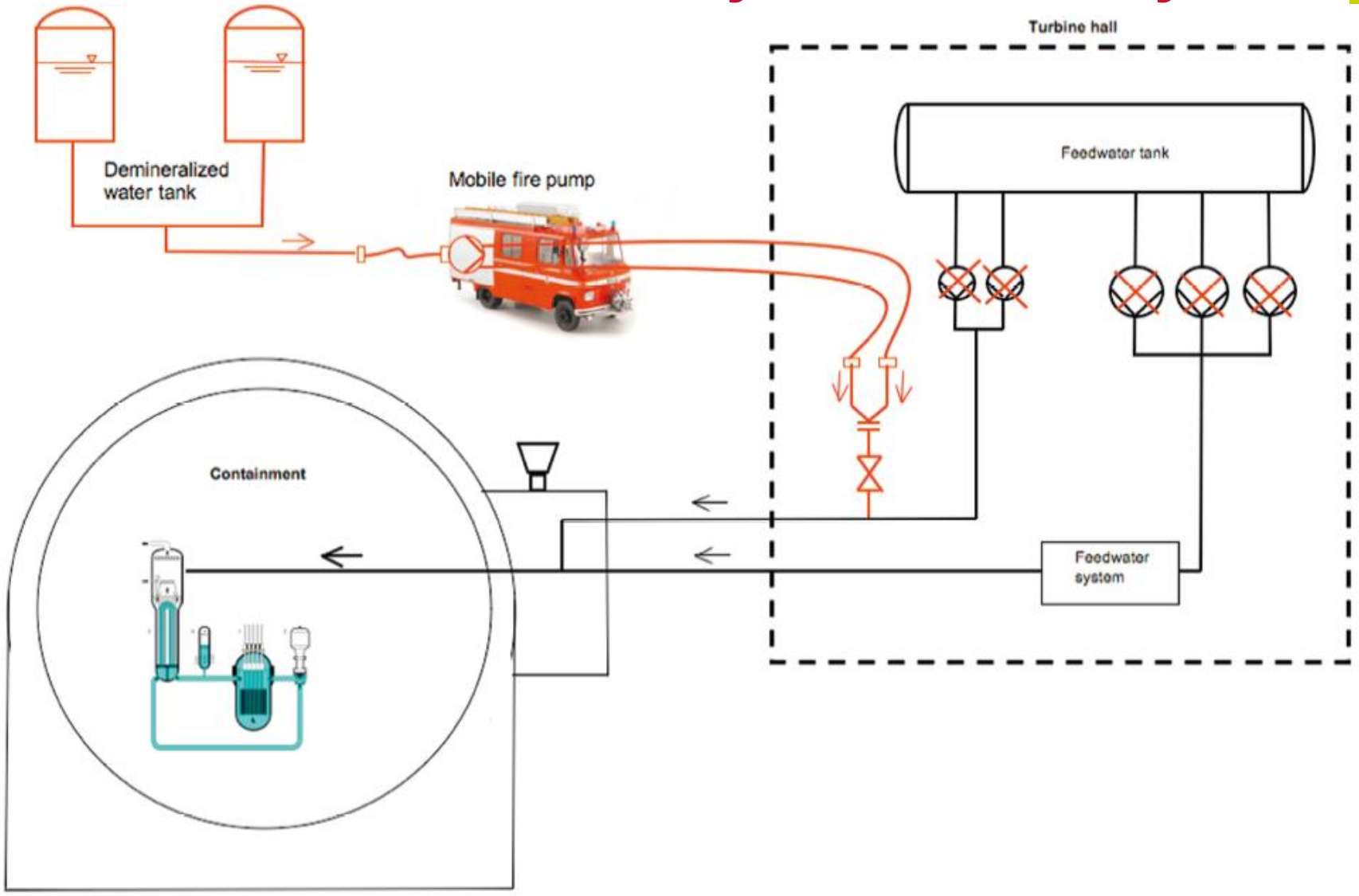
Mobile D4 Diesel (1 MVA) for Primary Residual Heat Removal up-to Grid Recovery (e.g. NPP Isar2)



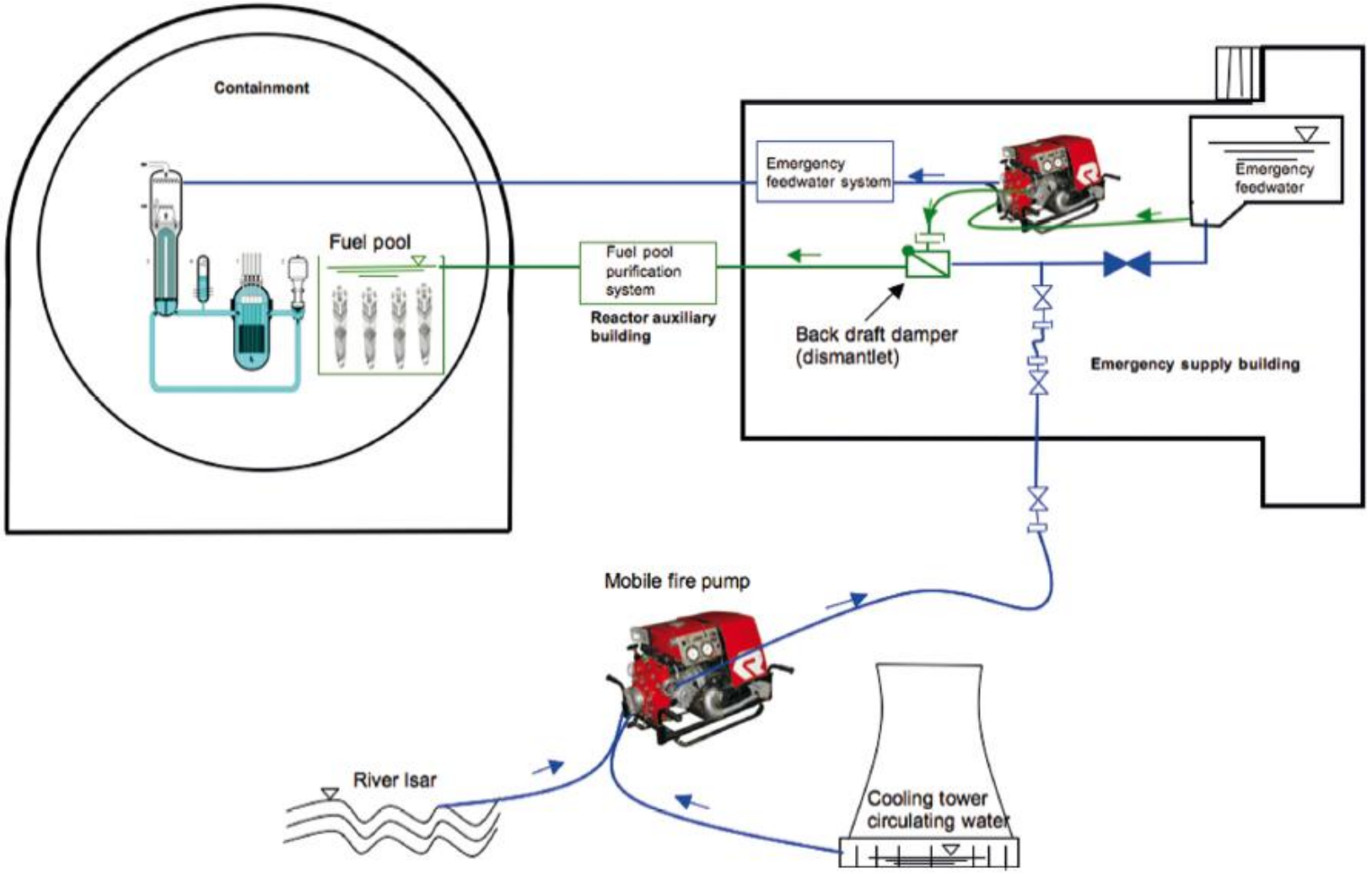
- 1.1 MW / 400V (10 kV)
- ~ 30 t, ~ 15 x 2.5 x 4 m
- Truck, no helicopter
- Parallel operation possible

- 1.1 MW, 400 V (tanks)
- 4.1 t, 3.7 x 1.5 x 1.5 m
- car trailer, light helicopter
- Parallel operation till 34 MW

Mobile Fire Pump Injection into SG via the Auxiliary Feedwater System



Back-up Mobile Pumps for EFW Pump and Tank by Water from River or Cooling Tower (NPP Isar2)



Innovations from KERENA
Inspirations for existing BWR Plants

Passive Safety Features of KERENA

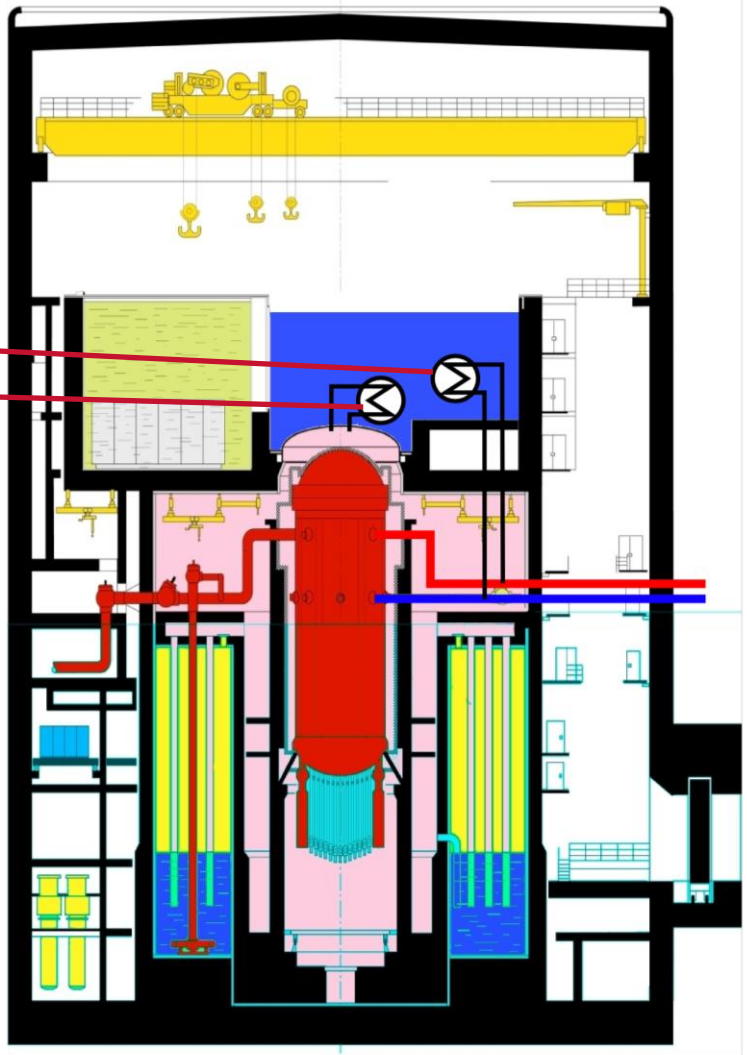
- Passive pressure pulse transmitter
- Containment condenser
- Emergency condenser
- RDB outer cooling

Solutions for BWR (Gundremmingen)

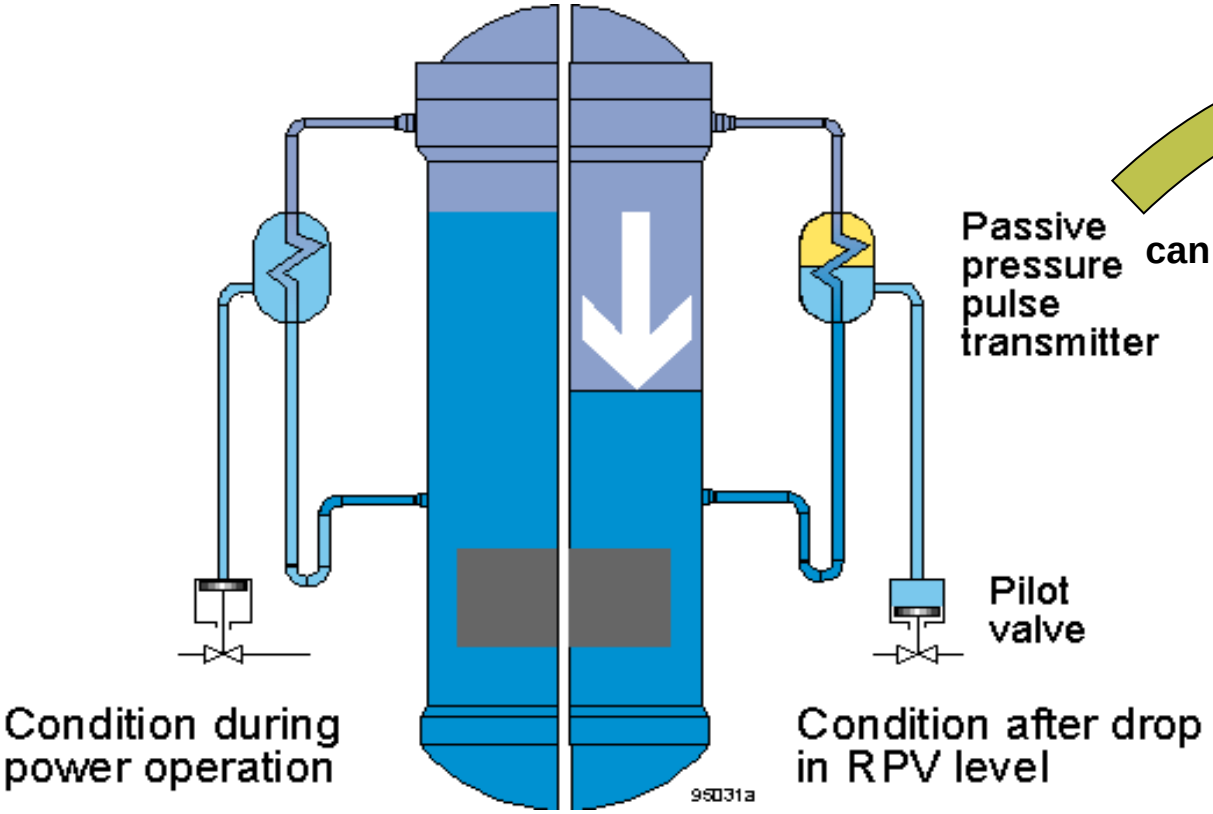
- Passive impulse sensor
- Passive residual heat removal chain
- RDB outer cooling
- Passive flooding of RPV
- Accident sequence using passive elements

Ultimate Heat Sink Solutions
Inspirations from AREVA's new NPP (2/2)

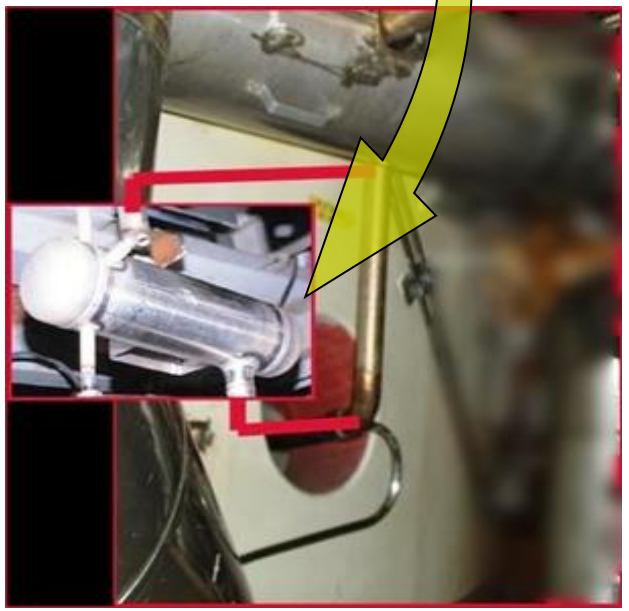
- **Inspirations for installed BWR from KERENA: Passive heat removal from core + containment**
- **Heat transfer from RPV and containment without electrical power supply**
- **Emergency condenser**
- **Containment cooling condenser**



Passive Pressure Pulse Transmitter



can easily be installed in existent RPV standpipe



- **Passive actuation of**
  - **SCRAM**
  - **Containment isolation**
  - **RPV depressurization**

Spent Fuel Pool
Cooling & Level Measurement under SBO

AREVA's references, e.g.:
NPP Gösgen and BWR KERENA

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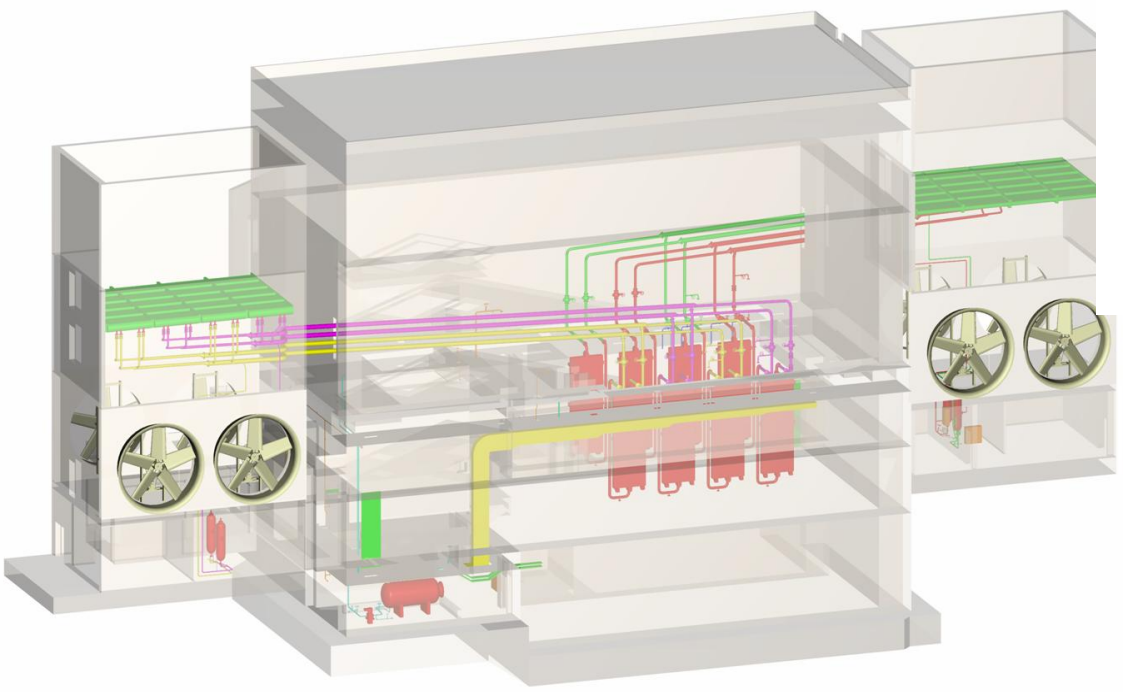
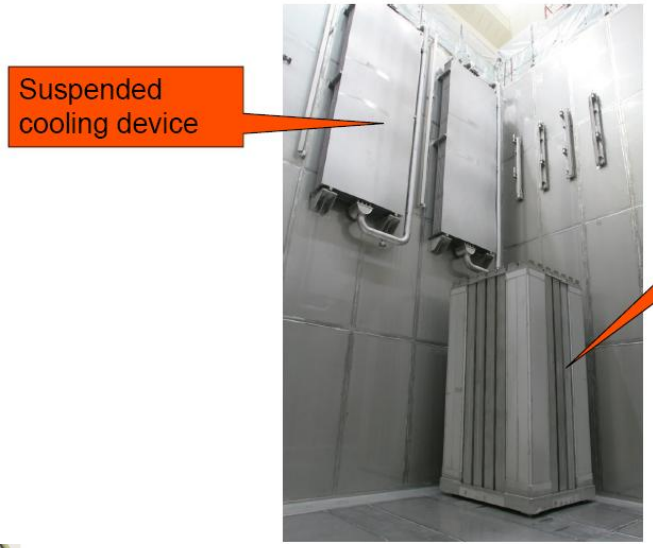
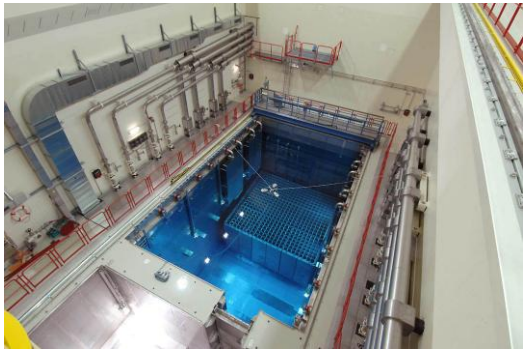
Spent Fuel Storage Pool
Passive Heat Removal

- **Example for residual heat removal from a Spent Fuel Storage Pool**
  - **Passive heat removal system at NPP Gösgen**

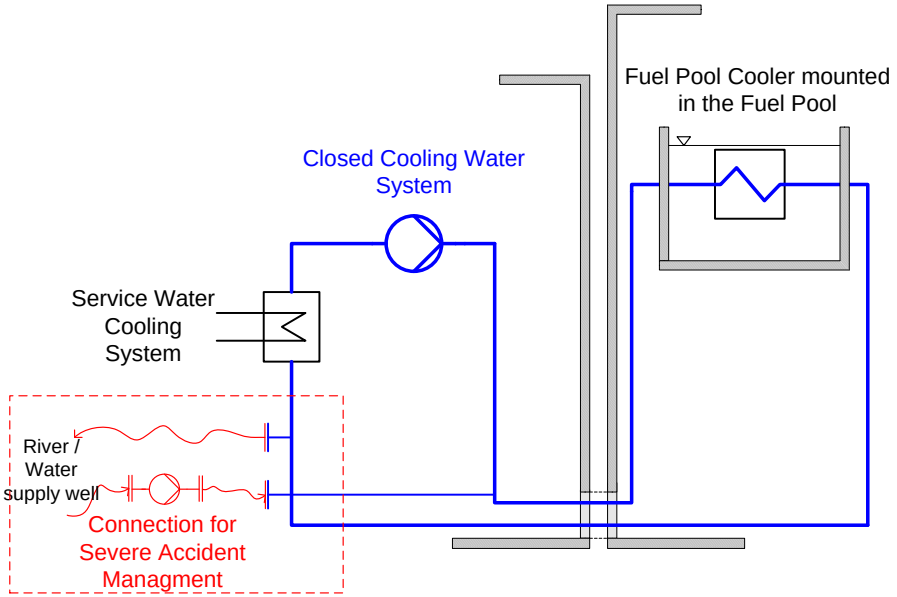


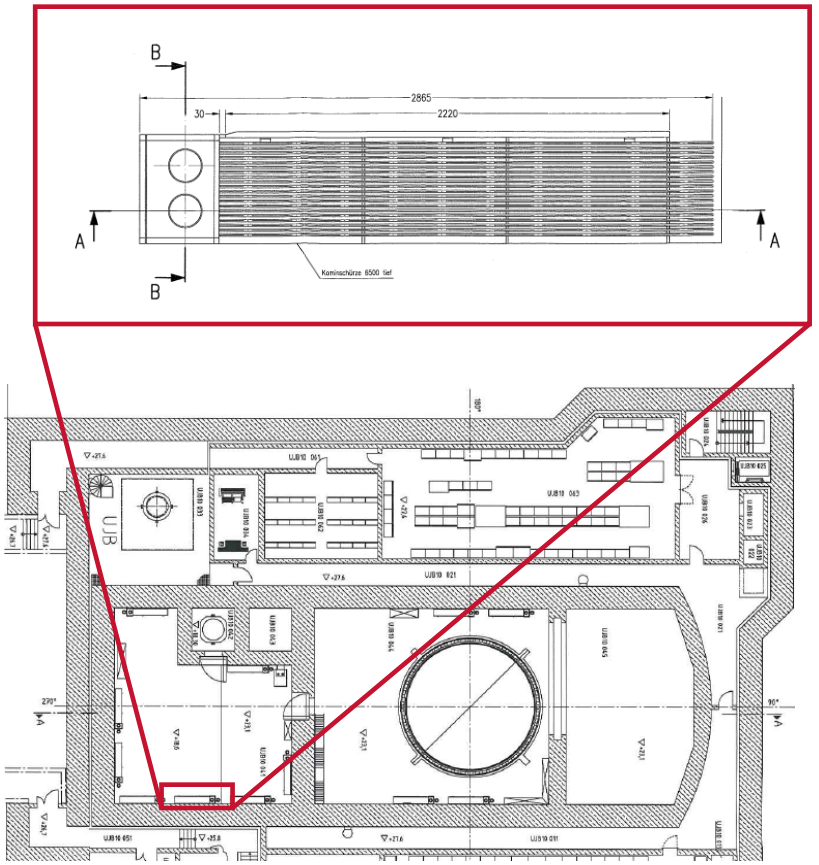




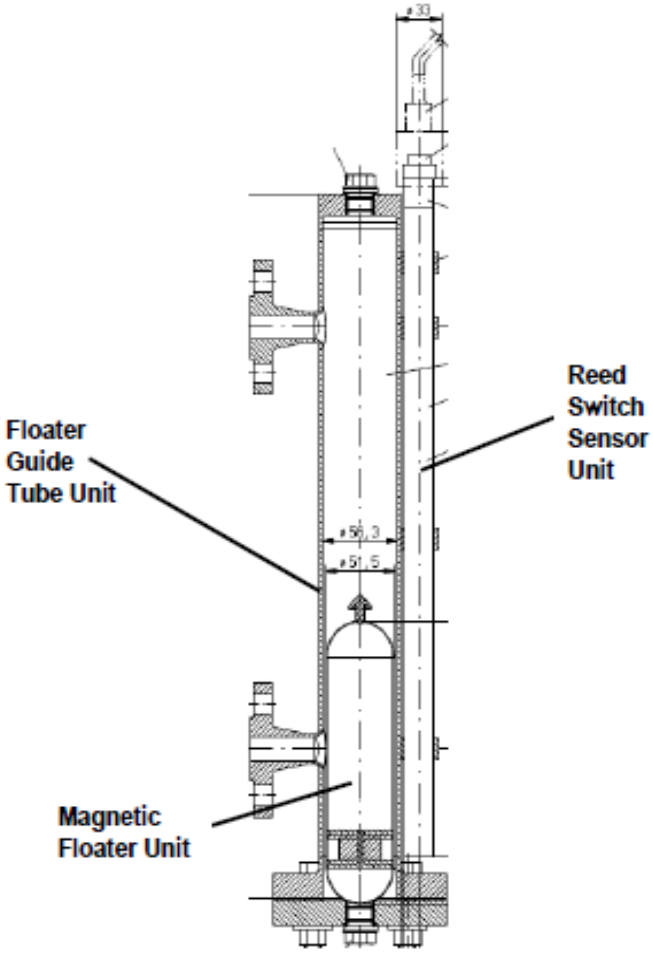
Spent Fuel Pool
Adaptation of Kerena (BWR) Cooling Solution

- **Natural circulation in the fuel pool**
- **Heat transfer via closed cooling water system to service water cooling system**
- **15 MW cooling capacity with KERENA cooling systems possible (8 cooler in fuel pool)**
- **Severe accident management cooling with fire protection water possible**
- **~ 4 m along the wall, 0.55 m width, chimney ~ 14 m**

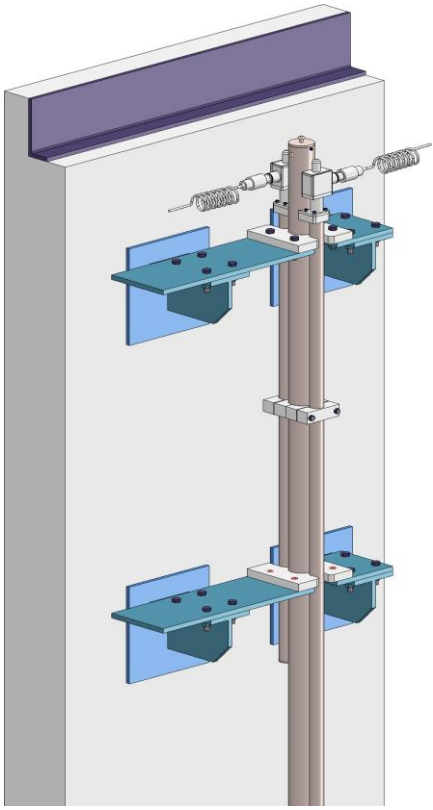




SFP Instrumentation
Accident Level Measurement Device



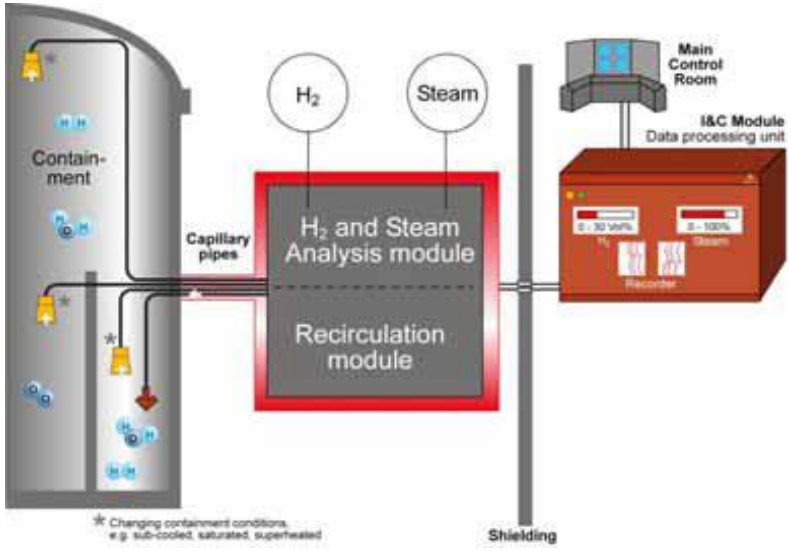
- **Magnetic floater unit moves with water level**
- **Magnetic field actuates nearest reed switch, changing the overall resistance for the current sent out by the transmitter**
- **Current magnitude ~ water level**
- **SBO: resistance is measured with an ohmmeter and correlated to level using a prepared table**
- **Sensor accuracy: 18 mm**
- **Measurement range: 0.4 m – 10 m**
- **Sensor response time: 1 s**
- **Accident and seismic qualified (156°C, 5 MGy)**



Other AREVA solutions:

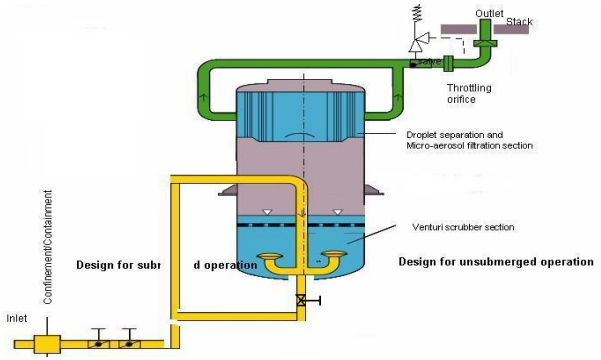
Through-Air Radar
Strain Gauge Pressure Transducer
Air Injection Level Measurement

Containment integrity protection and radioactive release prevention



Monitoring and sampling the containment atmosphere under severe accident conditions (HERMETIS, PRONAS)

Prevention of Hydrogen explosions



Filtered Venting
AREVA's references:
55 NPPs worldwide

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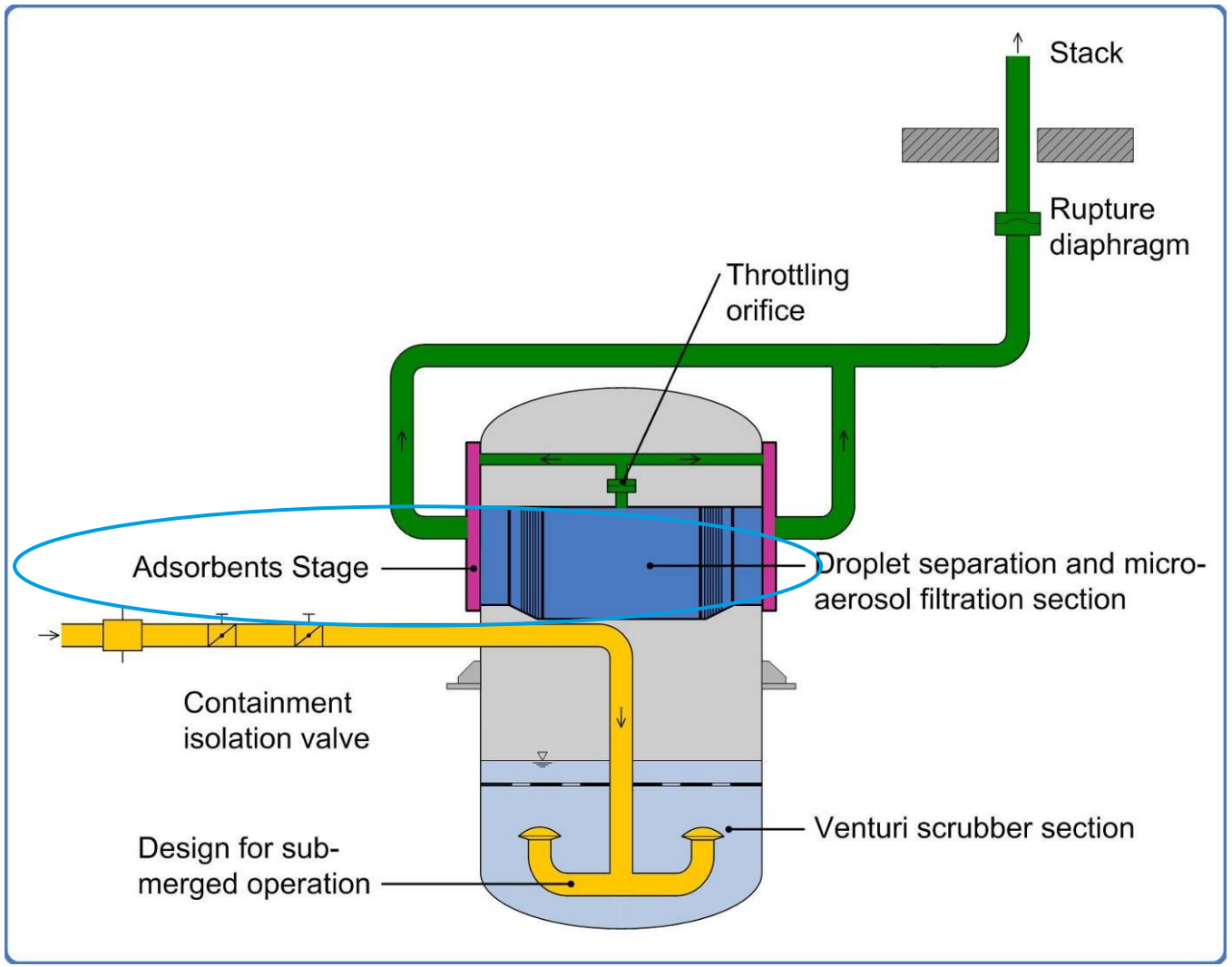
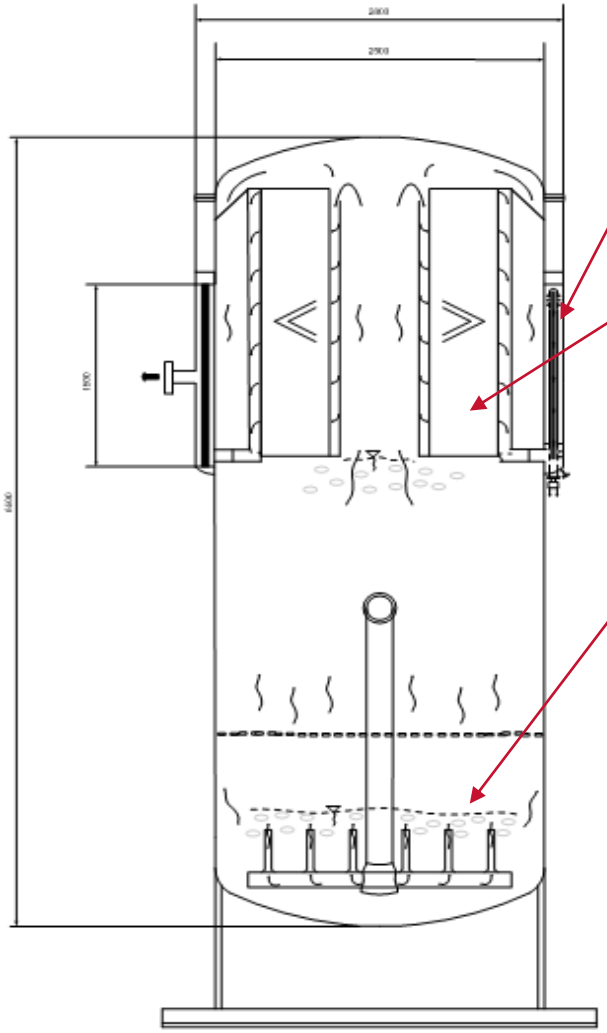
AREVA´s Standard Plus

High Speed Sliding Pressure Venting Plus

NEW !



Working Principle and Retention Rates



3. Sorbents Section

- Retaining of remaining and re-volatilized iodine (Elemental & Organic)

2. Metal Fibre Filter

- Large pre- and fine filter surfaces
- Penetrated fine aerosols retained
- Re-suspension aerosols captured

3. Venturi Scrubber

- Most aerosols retained
- Most elemental iodine retained (mid term)
- Large quantity of organic iodine retained (mid term)

4. Decontamination Factors:

Fine aerosols	> 10^4
Large aerosols	> 10^5
Aerosol iodine	> 10^6
Elemental iodine	> 10^3
Organic iodine	> 50 to 100

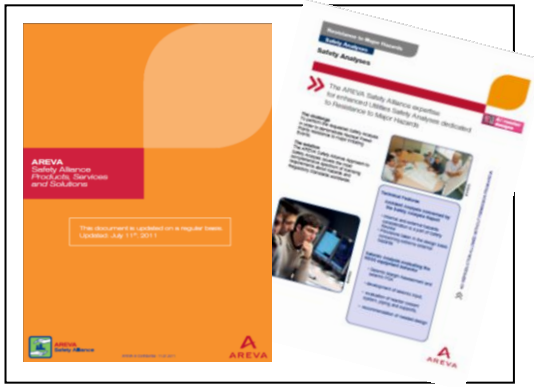
Working together with Operators Summary

- **Stepwise methodology to identify plant-tailored solutions to enhance the plant's robustness against beyond design hazards and afterwards and perform implementations while taking benefit from AREVA's referenced solutions**
  - **Improved protection against hazards to prevent the existing capabilities, e.g. primary heat sink, power supply.**
  - **Extension of the grace period ➔ more time for accident management, e.g. by bunkered hazards robust systems for "Secondary Feed&Bleed", primary and Spent Fuel Pool cooling.**
  - **Mobile backup solutions for water and power supply with accessible connection points.**
  - **Implementation of a full alternate emergency supply and heat removal system with a diverse heat sink ➔ Common Cause Failure for SBO and Loss of UHS ↓**
  - **Accident-proofed instrumentation**
  - **Filtered venting and hydrogen recombination to ensure containment integrity and mitigate the risk of r/a releases into the environment.**

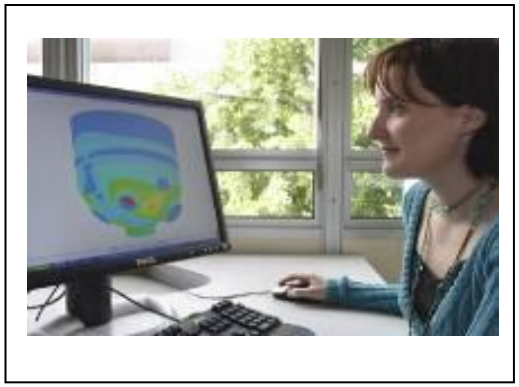
AREVA has references for all steps and is looking forward to a mutual satisfactory cooperation

AREVA's Post-Fukushima Initiative

- **A catalogue of 35+ selected products and services across AREVA's full nuclear portfolio**



- **A dedicated R&D organization for prioritized projects**



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Safety Alliance

Working together
AREVA with Operators

NUCLEAR EXECUTIVE MEETING
Paris, September 29-30, 2011

Nuclear Fleet Safety Seminar
Frankfurt, May 9 -10, 2012

Public Confidence Seminar
Paris, June 18 -19, 2012

Nuclear Economics Seminar
London, September 14, 2012

NUCLEAR EXECUTIVE MEETING
Paris, October 11-12, 2012

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End of presentation AREVA's Solutions for Post-Fukushima Safety Enhancements

Dr. Rolf Janke
Director Strategy and Technical Development / IBU-G
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