Full System Decontamination Prior to Decommissioning

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Comparison of Decontaminations Performed at PWRs Unterweser & Neckarwestheim 1 and BWR ISAR 1

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Chemical Decontamination

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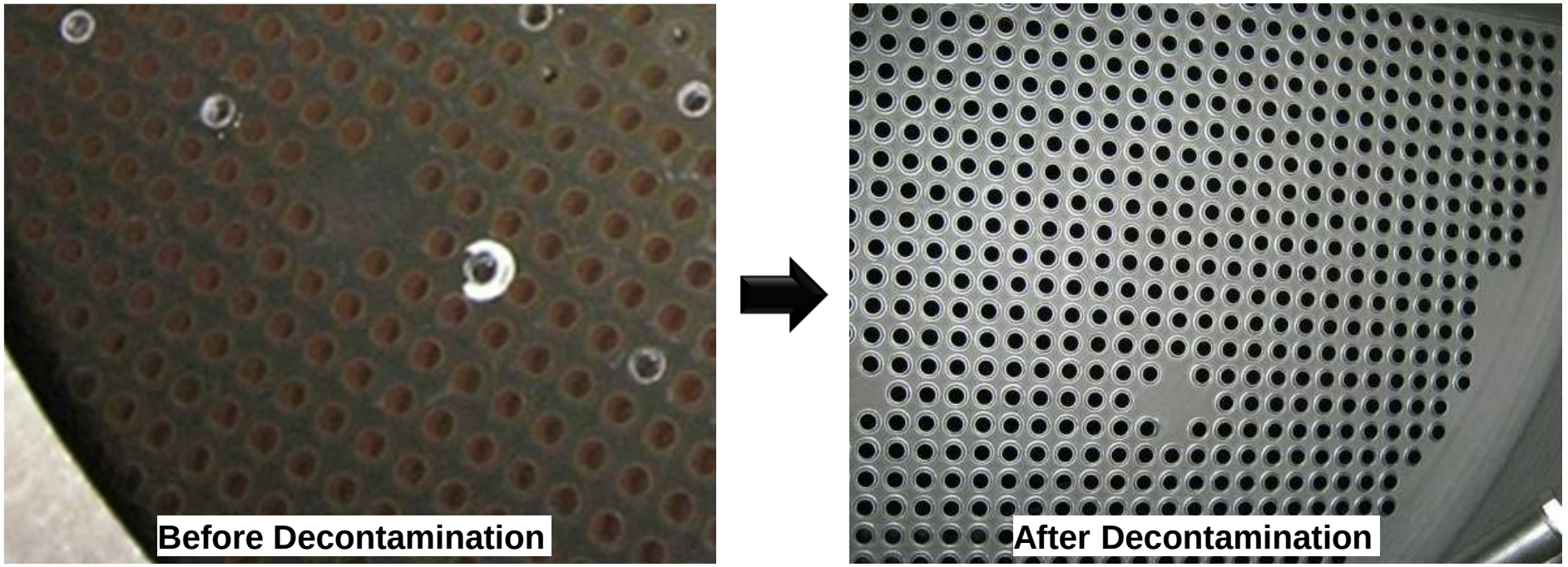
Chemical Decontamination

Source term reduction / Effective removal of activity inventory



STEAM GENERATOR TUBE SHEETS BEFORE AND AFTER CHEMICAL DECONTAMINATION WITH AREVA HP CORD UV *Pihotos: EdF*

- **During plant operation, activated corrosion products accumulate on RCS surfaces**
- **Removal of oxides is very effective in the removal of high activity inventory** ***(excepted: activated areas e.g. RPV, including internals)***
- **Low Dose Rates and High decon factors regularly obtained**

Chemical Decontamination
Typical Applications for BWRs and PWRs

BWR

- **Sub-System/Component Decons**
  - RWCU
  - RRS
  - Recirc pumps
  - RHR
  - Spent Fuel Pool Cooling
- **Full System Decontamination**
  - Decommissioning
  - Operating NPPs

PWR

- **Sub-System/Component Decons**
  - RCS
  - Regenerative Heat Exchangers
  - CVCS
  - Pressurizer
  - Pressurizer Spraylines
  - Steam Generator
- **Full System Decontamination**
  - Decommissioning
  - Operating NPPs

Decontamination is an approved and recommended procedure:

- Prior to repairs, inspections (ISI/NDE) and component replacement
- **Target:**
  - Local dose reduction at components and in working area
  - CRE reduction

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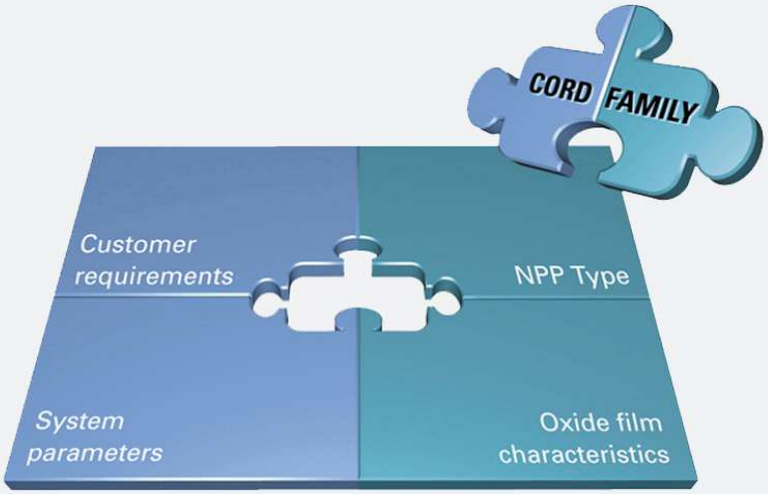
The AREVA CORD® Family Concept & AMDA®
Is a Tailored Approach to Fulfill all Requirements

CORD Chemical Oxidation Reduction Decontamination

AMDA Automatic Mobile Decontamination Appliance

- **CORD Family Concept**
  - Developed and patented decontamination processes
  - More than 500 decontamination projects worldwide
  - All NPP designs (PWR, BWR, HPWR)
- **AMDA – AREVA Decon Equipment**
  - Automated & Modular Flexible & Reliable
  - More than 30 years operational experience
- **Advantages**
  - Tailored concept
  - Minimum waste
  - Excellent and reproducible results
  - High planning safety



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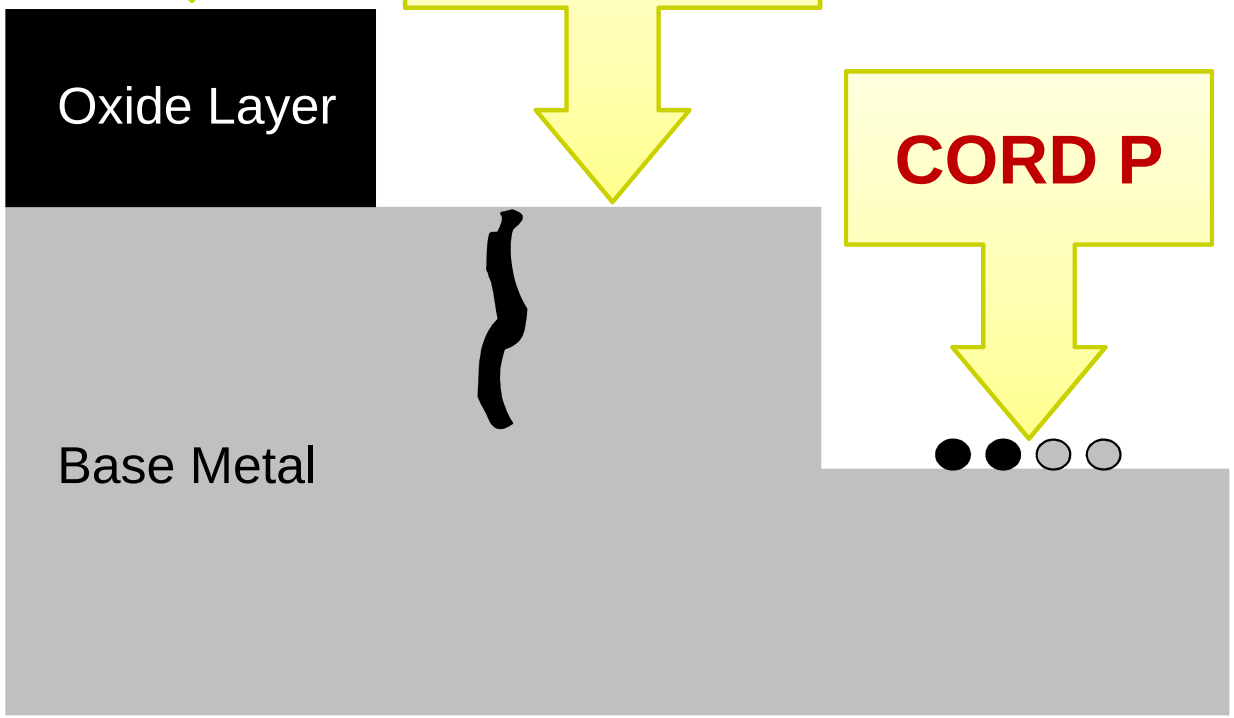
The AREVA CORD® Family Concept
Main Chemical Processes for Decommissioning

CORD UV → **Removal of Oxide Layer only**

CORD D UV → **Removal of Base Metal possible**

CORD P → **Removal of loosely adhered Particles and Actinides**



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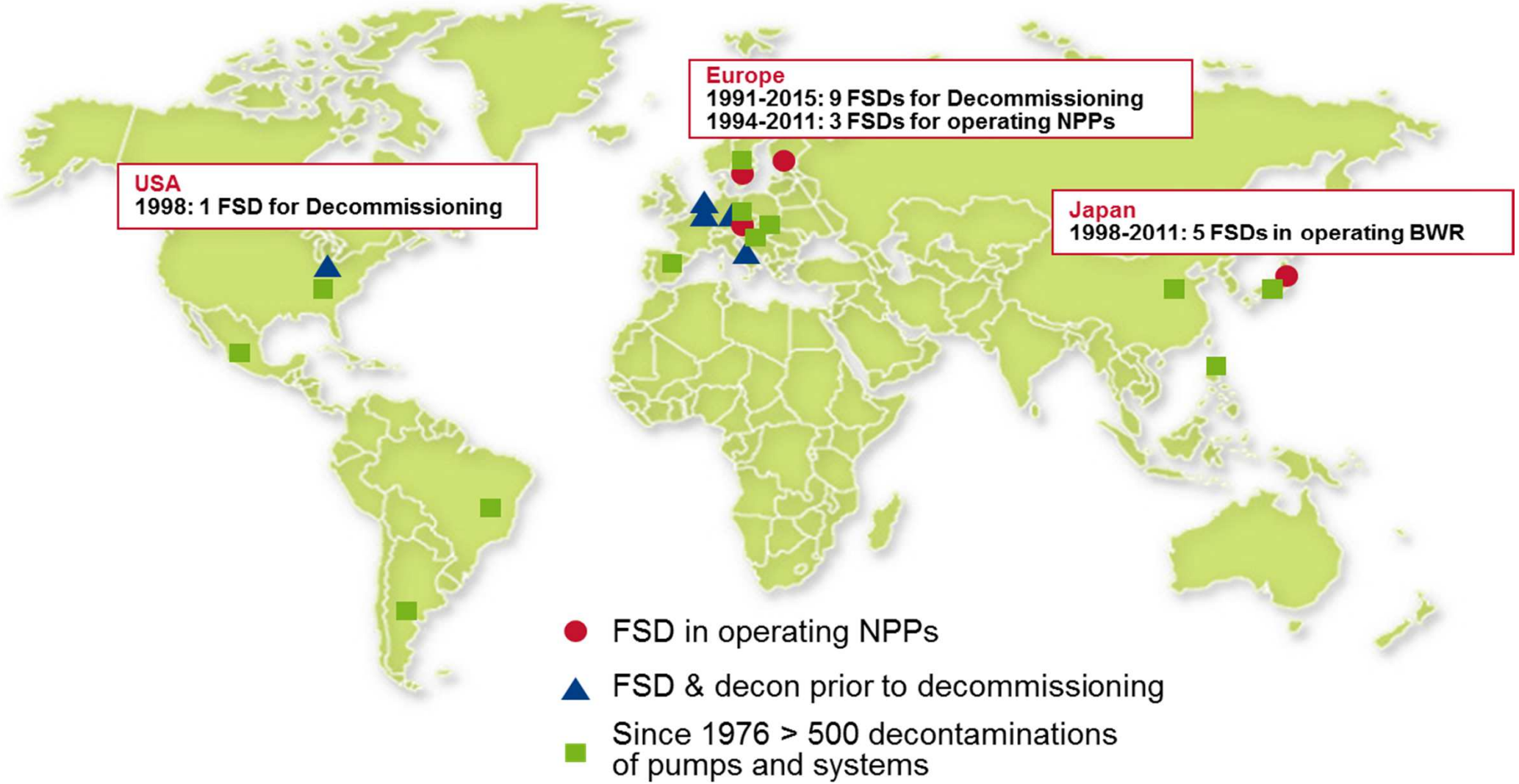
AREVA Worldwide Experience



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Full System Decontamination for Decommissioning

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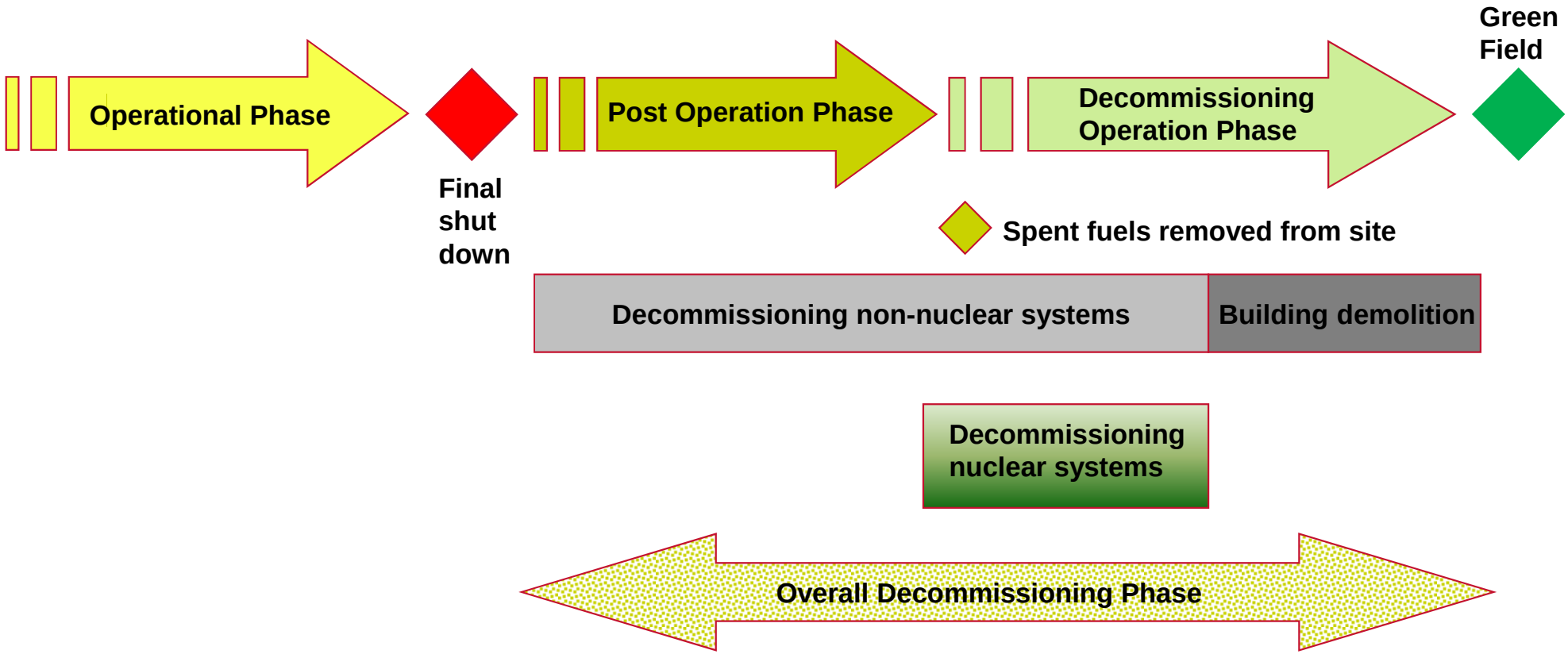
Decommissioning of a Nuclear Facility
General Schedule



Recommended Scenario for Full System Decontamination

FSD planning phase

FSD performance 1-2 years after final shutdown

Sub-system decontamination

Decontamination replaced parts

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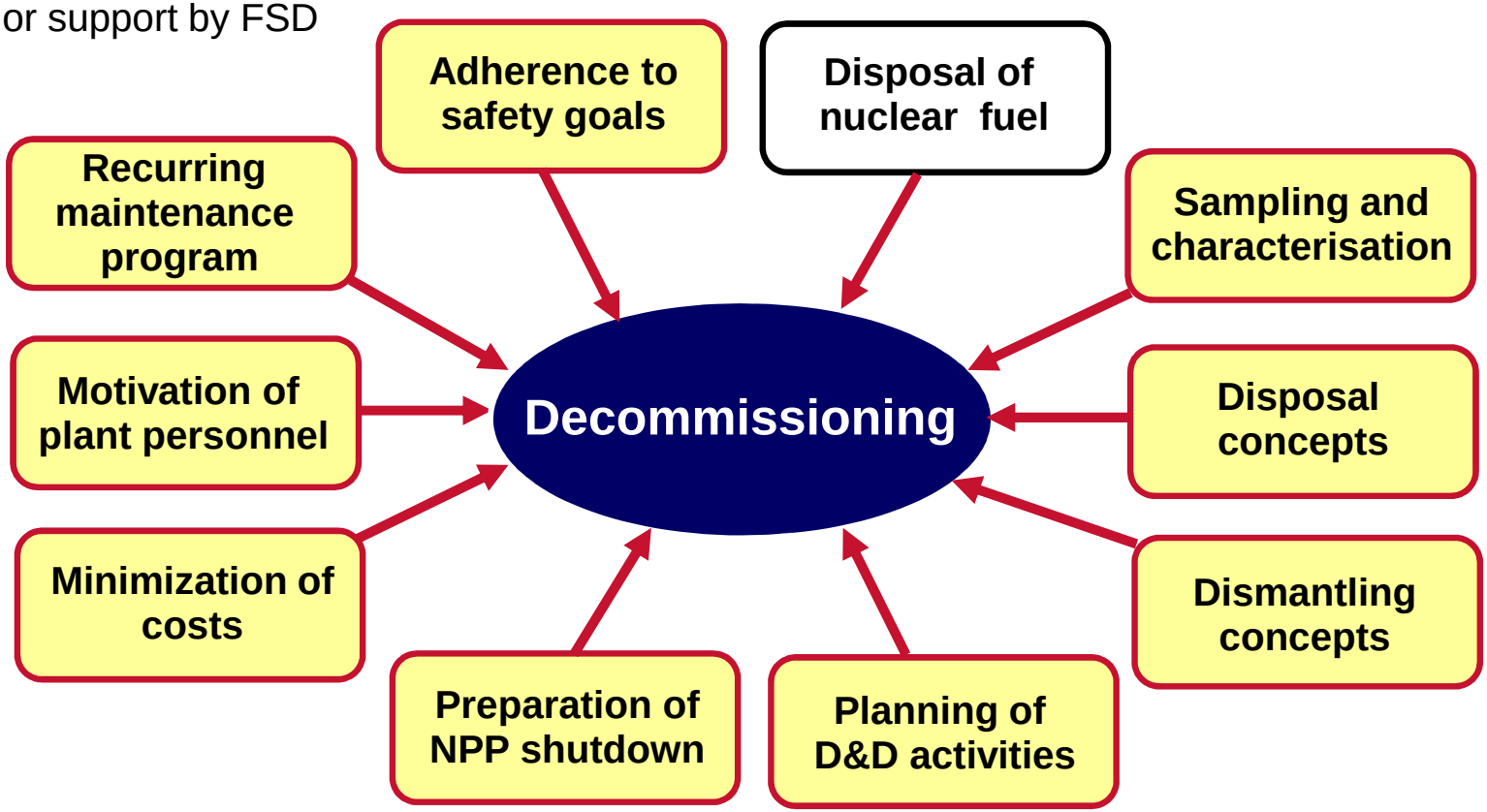
FSD prior to Decommissioning
Simplification of Decommissioning in many Aspects

= major support by FSD



FSD is the key for quick, substantial dose reduction of the primary and auxilliary systems inconjunction with D&D planning to best accomplish the goals of the ALARA principle during decommissioning activities.

FSD prior to Decommissioning
Advantages of FSD during Post-Operation Phase

- All power plant systems are operable with no limitations
- Experienced Power Plant Operations, Maintenance and Engineering Staff available
  - Time and cost savings during planning phase of FSD
  - Risk minimization during FSD site performance
- Maximum reduction of activity inventory in early stage
- Simplification of site characterization
- Early shut down of systems after FSD or system declassification possible resulting in cost savings
- Simplification of maintenance program
- Overall Decommissioning planning simplified due to low dose and contamination levels

FSD during Post-Operation Phase

Recent Results

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Full System Decontamination 2012/2013: PWR Unterweser – PWR Neckarwestheim 1

- **Type:** PWR (4x SG)
- **Capacity:** 1410 MWe
- **Start of operation:** 1979
- **End of operation:** 2011

- **Type:** PWR (3x SG)
- **Capacity:** 840 MWe
- **Start of operation:** 1976
- **End of operation:** 2011

- **Decontamination:**
  - **Full System Decontamination (Simultaneous treatment of complete primary circuit & aux. Systems)**
  - **Ensure structural integrity (stand-by, possibility of return to operation)**

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Full System Decontamination KKU / GKN1
General Data

Basic Data	NPP Unterweser	NPP Neckarwestheim-1
Reactor Type	PWR, 4 Loop, 1410 MWe	PWR, 3 Loop, 840 MWe
Decontamination Area	Primary Circuit / 4 RHR Systems / CVC System	Primary Circuit / 2 RHR Systems / CVC System / RWCU System
Auxiliary Systems	RCS / WWTS / NES / RWCU	RCS / WWTS / NES / RWCU
Total Surface Area	22.500 m^2 (~ 278000 ft^2)	18.000 m^2 (~ 194000 ft^2)
Total System Volume	540 m^3 (~ 142000 gal)	360 m^3 (~ 95100 gal)
Reactor Coolant Pump Supplier	KSB	Andritz
Operational Pressure	~ 21 bar (~ 300 psi)	~ 26 bar (~ 375 psi)
Operational Temperature	60 - 95 °C (140 - 200 °F)	60 - 95 °C (140 - 200 °F)
AMDA Connection Points	RHR 30 / 40	RHR 10 / 20
Application Time	35 days	25 days
Collective Radiation Exposure for on-site activities	70 mSv	61 mSv

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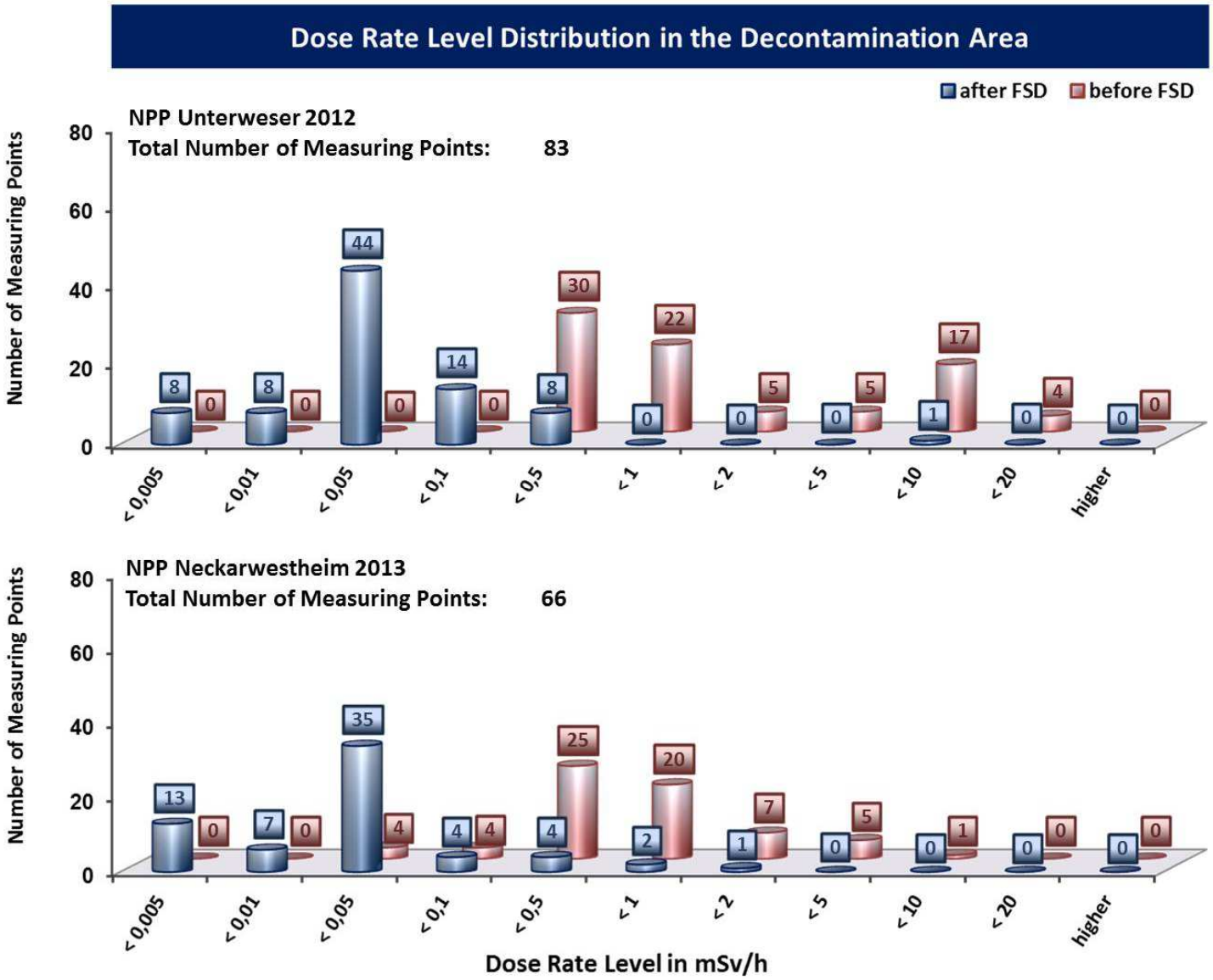
Full System Decontamination KKU / GKN1
Dose Rate Distribution before / after FSD



- **Prior to FSD**

  High dose rate Level (>> 0.5 mSv/h)

- **After FSD**

  Very low dose rate Level (<< 0.5 mSv/h)

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Full System Decontamination KKU / GKN1
PWR KKU 2012 – inside SGs

Dose rate inside water chamber

before FSD: 150 mSv/h (15 Rem/h) → **after FSD: 3 mSv/h (0.3 Rem/h)**

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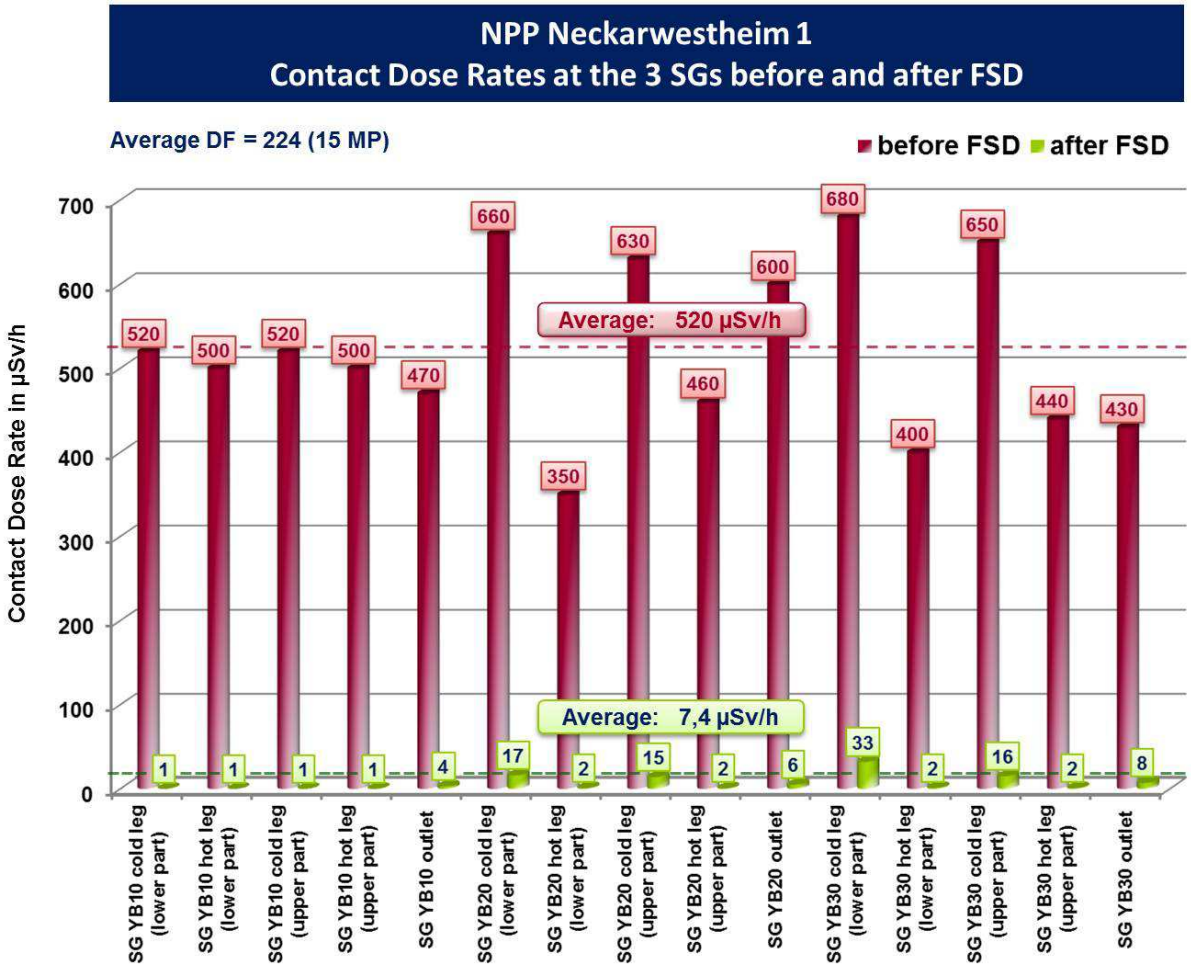
Full System Decontamination KKU / GKN1
PWR GKN1 2013 – Results



Very low contact dose rates at heavy components facilitates D&D planning and performance

RHR pump inspection after FSD no detrimental effect on materials

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Full System Decontamination KKU / GKN1
FSD Results - Summary

Activity & Corrosion products removed	NPP Unterweser (KKU)	NPP Neckarwestheim-1 (GKN1)
corrosion products (Fe, Cr, Ni)	459 kg	260 kg
total Activity removed (> 99% Co-60)	9.1 E+13 Bq (2,460 Ci)	1.1 E+13 Bq (297 Ci)
Decon Factors (DF) achieved		
DF overall	94.5 (83 MP)	81 (66 MP)
DF Primary circuit (Loop & PZR)	158 (26 MP)	31 (20 MP)
DF SG tubing area	147 (16 MP)	224 (15 MP)
DF Auxiliary Systems (RHR / CVCS)	35 (41 MP)	44 (31 MP)
Waste		
Ion Exchange Resins	21 m³ (planned 23 m³)	11 m³ (planned 15 m³)

MP = measuring point

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Full System Decontamination in 2015: BWR KKI1 – Southern Germany

- **Type:** BWR
- **Capacity:** 912 MWe
- **Start of operation:** 1977
- **End of operation:** 2011

Picture: EON

- **Decontamination:**
  - **Full System Decontamination (RPV incl. steam dryer & aux. Systems)**
  - **Ensure structural integrity (stand-by, possibility of return to operation)**

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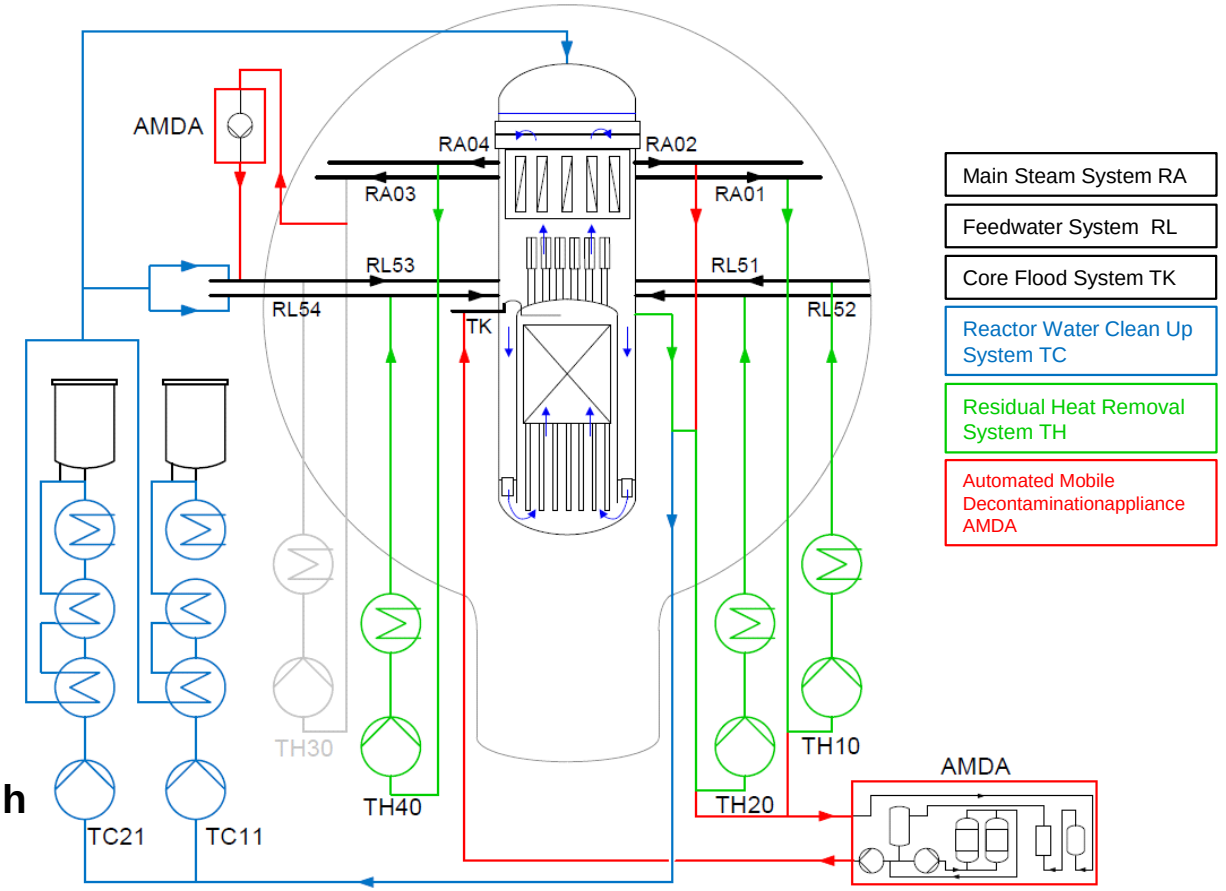
Full System Decontamination KKI 1
BWR KKI 1 - Decontamination Area

Decontamination Area			
System	**Surface**	**Volume**	**Material of Construction**
Mainsteam system RA*	120 m²	10 m³	1.6310/1.6368
Feedwater system RL*	111 m²	9 m³	1.6368
Reactor Water Clean Up System TC	324 m²	7 m³	1.4550/1.4541
Residual Heat removal system TH10/20/40*	1742 m²	58 m³	1.4550/1.4541
Core Spray System TK*	82 m²	6 m³	1.4550/1.4541
RPV and Internals YD/YE	7452 m²	485 m³	1.4550/1.4551 1.4541/1.4571

* partially included in Decontamination Area

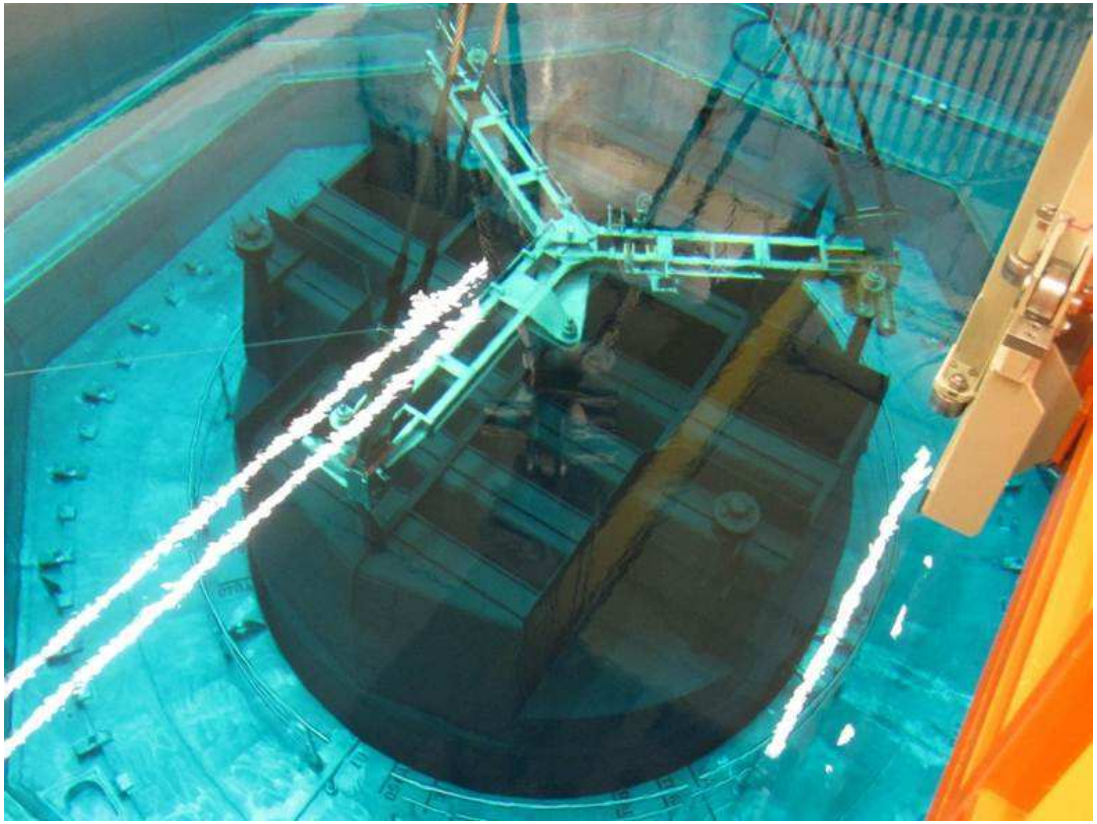


Boundary Conditions for FSD

- **Mixed Materials in Decon Area**
  - Stainless Steel / Carbon Steel
- **Specific FSD performance to ensure a high decon effect on the steam dryer and the water separator by**
  - Adapting flow rates of auxiliary systems
  - Adapting water level inside RPV

Full System Decontamination KKI 1
BWR KKI 1 – Steam Dryer Results

Steam Dryer in underwater storage location prior to FSD in 2012



- **Major Decontamination Target**
  - **Removal of Oxide layer and Particles**
  - **Minimization of overall activity inventory**
  - **Minimization of contact dose rates**

…to the greatest possible extent to facilitate dry cutting of the STEAM DRYER during D&D of KKI 1

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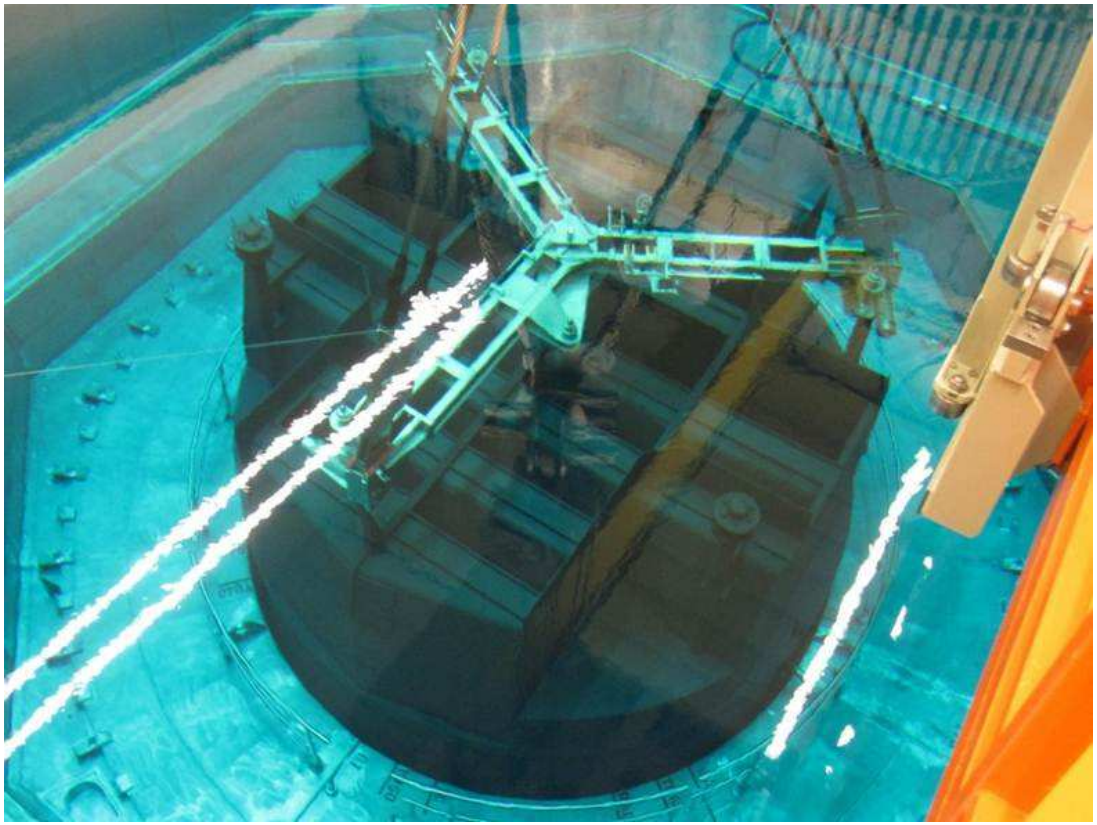
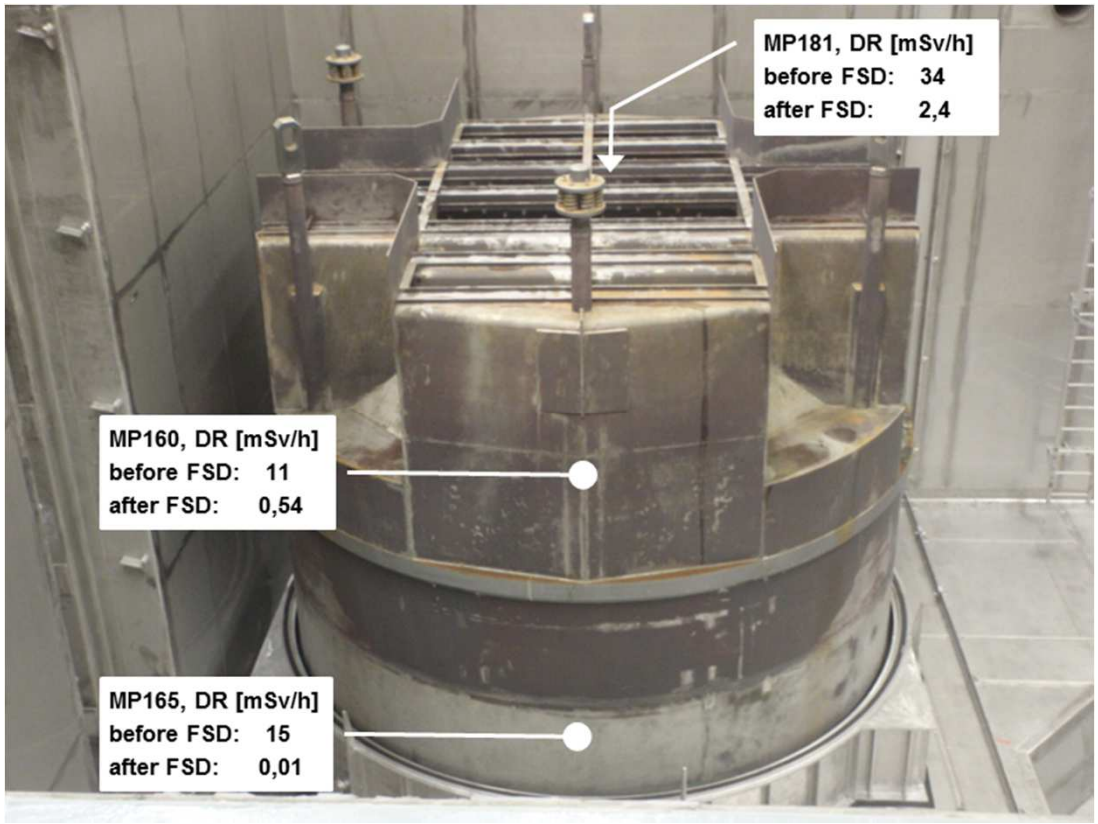
Full System Decontamination KKI 1
BWR KKI 1 – Steam Dryer Results

Steam Dryer in underwater storage location prior to FSD in 2012



Steam Dryer in storage location after FSD 2015 in dry condition



no airborne related activity detected

Follow up of dry cutting techniques by KKI

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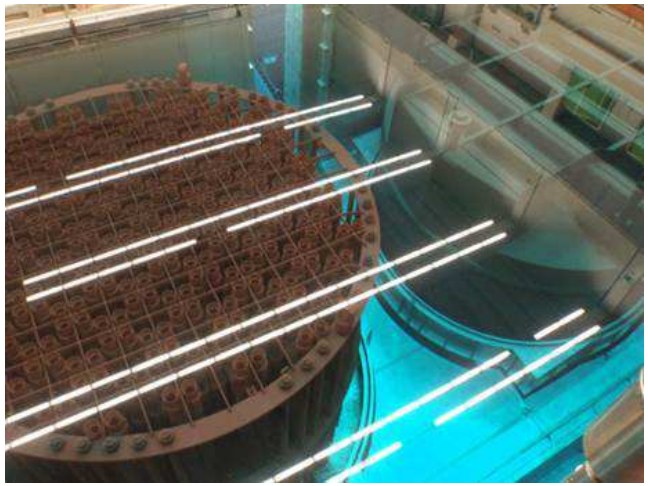
Full System Decontamination KKI 1
BWR KKI 1 – Water Separator Results

Water Separator prior to FSD in 2012 stored under water at storage location



Water Separator after FSD partially above water level

Contact Dose Rate comparison water separator prior to and after FSD
(measurement under water in mSv/h)

MP Nr.	0°		90°		180°		270°	
	prior to FSD	*after FSD*	*prior to FSD*	*after FSD*	*prior to FSD*	*after FSD*	*prior to FSD*	*after FSD*
1	64,1	0,20	82,1	0,18	69,5	0,20	76,7	0,2
2	82,7	0,14	70,8	0,18	94,5	0,14	76,4	0,2
3	128,8	0,10	180,0	0,16	141,1	0,10	162,8	0,16
4	74,7	0,09	92,0	0,11	89,6	0,07	81,1	0,08
5	54,2	0,33	50,8	0,26	61,6	0,025	52,6	0,56
6	47,7	0,25	31,8	0,03	51,8	0,34	31,1	0,42
7	40,7	0,68	17,8	1,3	43,9	0,60	19,0	1,45
8	49,7	5,9	21,0	13,6	53,1	5,9	22,9	15,2
9	84,6	24,0	42,0	44,2	87,8	26,6	40,9	43,2
10	8,8	3,45	8,1	3,3	6,1	2,8	7,5	2,25
11	10,0	2,76	9,2	2,0	7,3	2,8	8,3	0,8
12	1,6	1,32	1,2	0,65	0,9	0,36	1,2	0,82

area of activation

no airborne related activity detected during lifting

loosely adhered sediments on horizontal surfaces can be removed easily by flushing

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Full System Decontamination BWR KKI 1
FSD Results - Summary

Corrosion- and Activity removed	
corrosion products (Fe, Cr, Ni)	**337 kg**
Total activity removed (>99% Co-60)	**1,5 E13 Bq (405 Ci)**
via Ion Exchange Resins	**1,2 E13 Bq (324 Ci)**
Via Filtration	**3 E12 Bq (81 Ci)**
Ion Exchange Resin consumption	**9,8 m³**
Overall Decon Factor achieved (DF)	
Total Decon Area without Internals	**39**
Steam Dryer	**46**

- **Inspection of Piping after FSD in cooperation with TÜV SÜD Germany**
  - **Metallically clean surfaces**
  - **No detrimental effects on material detected**

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Full System Decontamination BWR KKI 1
Application of CORD P in the RWCU System

- **The CORD P Process:**
  - **Very effective removal of loosely adhered Particles and Actinides from the system surfaces**
  - **Application after the removal of the oxide layer and/or after the removal of base material**
  - **CORD P uses a surfactant and is applied at neutral pH**
  - **High Material Compatibility**
  - **Low chemical concentrations necessary**
  - **Cleaning of solution by Filtration and Ion exchange**
  - **Only non-regenerative chemical process inside the CORD Family**

Full System Decontamination BWR KKI 1
Application of CORD P

Decon loop water prior to the addition of the surfactant

Particle mobiliazation after surfactant addition

Cleanup via Filtration and Ion exchange

Full System Decontamination BWR KKI 1
Application of CORD P - Results

Smeartests prior to and after CORD P application
Contamination in Bq/cm²

Smear Test Nr.	*Prior to CORD P*	*after CORD P*
1	335	38
2	220	35
3	230	15
4	120	15
5	115	21
6	45	10
7	50	5
8	60	6
9	65	5
10	65	6

Inside of RWCU Cooler
Prior to (left) and after CORD P

Conclusion

Decontamination prior to Decommissioning

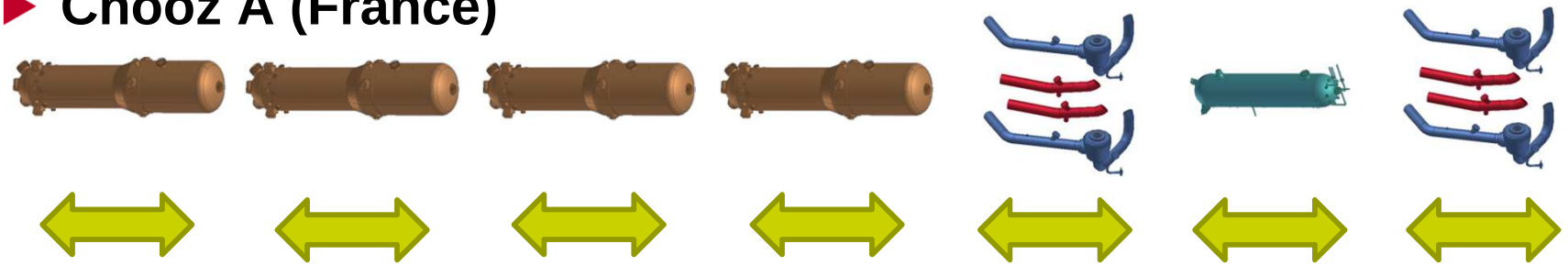
- FSD is worldwide the most accepted approach for decontamination prior decommissioning
- AREVA's Decontamination Technology is a mature, reliable and proven technology - Virtually any decontamination target can be achieved safely and efficiently
- Treating single components separately is more time consuming than a simultaneous Full System Decontamination, but feasible
- Waste handling meets site procedures and final storage requirements

- **Recommendation:**
  FSD for Decommissioning as early as possible after shut down including a tailored approach to fulfill all specific needs

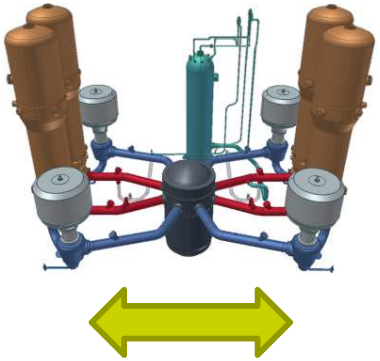
Timeline comparison
FSD vs single component

2011		2012												2013				
11	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05

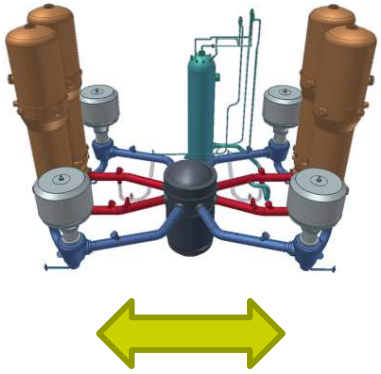
- **Chooz A (France)**



- **Unterweser (Germany)**



- **Neckarwestheim 1 (Germany)**



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