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Full System Decontamination – Sustainable Dose Reduction for Operating Nuclear Power Plants

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Decontamination
Typical Applications for BWRs and PWRs

BWR

- RWCU
- Recirc
- Recirc pumps
- RHR
- Pool cooling system
- **Full System Decontamination**
  - Decommissioning
  - **Operating NPPs**

PWR

- RCP
- Reg. Heat exchangers
- VCS
- Pressurizer
- Pressurizer – Spraylines
- Steam Generator (water chamber)
- **Full System Decontamination**
  - Decommissioning
  - **Operating NPPs**

Decontamination is today an approved procedure:

- Prior to repairs, inspections (NDE) and component replacement
- Target:
  - Local dose reduction at components and in working area
  - Dose reduction for the scheduled measures

Examples for Man-rem Savings for Repairs / Maintenance / Replacements

NPP	System/Component	DF	Year	Savings [mSv]
Oskarshamn 2	Recirc-Pump-Housing (in situ)	9	08/1991	400
Würgassen	Recirc-Loop	26	06/1991	2000
KWW	Recirc-Loop	20	06/1992	2000
BR3	FSD (Decommissioning)	10 to 60	05/1991	7500
Kahl	FSD (Decommissioning)	20 to 120	11/1993	2200
Oskarshamn 1	FSD	20 to 1000	01/1994	20000
Loviisa 2	FSD	14 to 153	08/1994	> 8000
Borssele	RHR	17	01/1997	438
1 Fukushima 3	FSD	43 to 72	06/1997	70000
Laguna Verde 1	Recirc, RWCU	30	03/1998	5000
Krümmel	RWCU, RHR	20 to 103	07/1998	6900
Connecticut Yankee	FSD (Decommissioning)	15.7	07/1998	> 10000
1 Fukushima 2	FSD	68 to 108	08/1998	140000
Sta. Maria de Garoña	Recirc-Loops	40.7	01/1999	780
1 Fukushima 5	FSD	35 to 83	01/2000	50000

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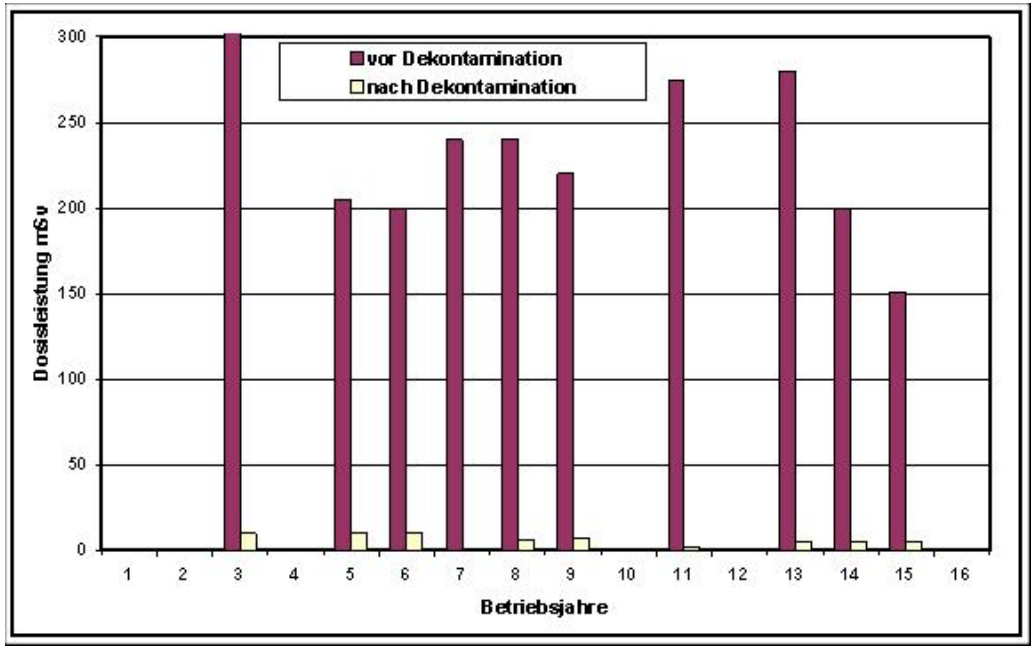
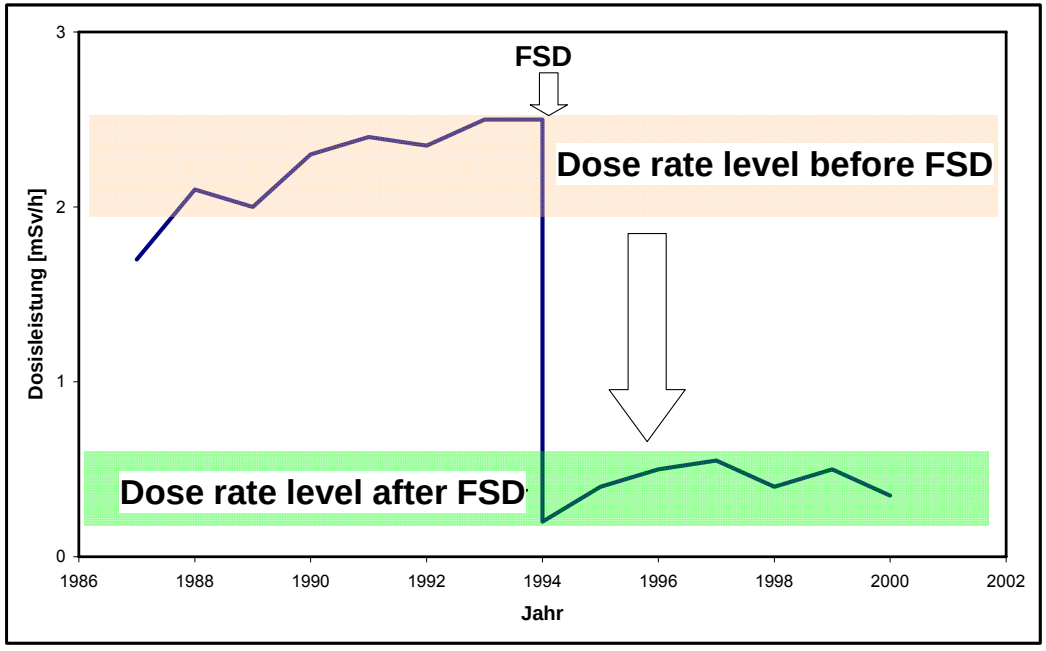
Recontamination after Decontamination is lower, with bigger Decon area and more removed Activity Inventory

RCP: fast recontamination (shown with dose rates before Decontamination)



Siemens PWR

FSD: slow and low recontamination



VVER Loviisa 2

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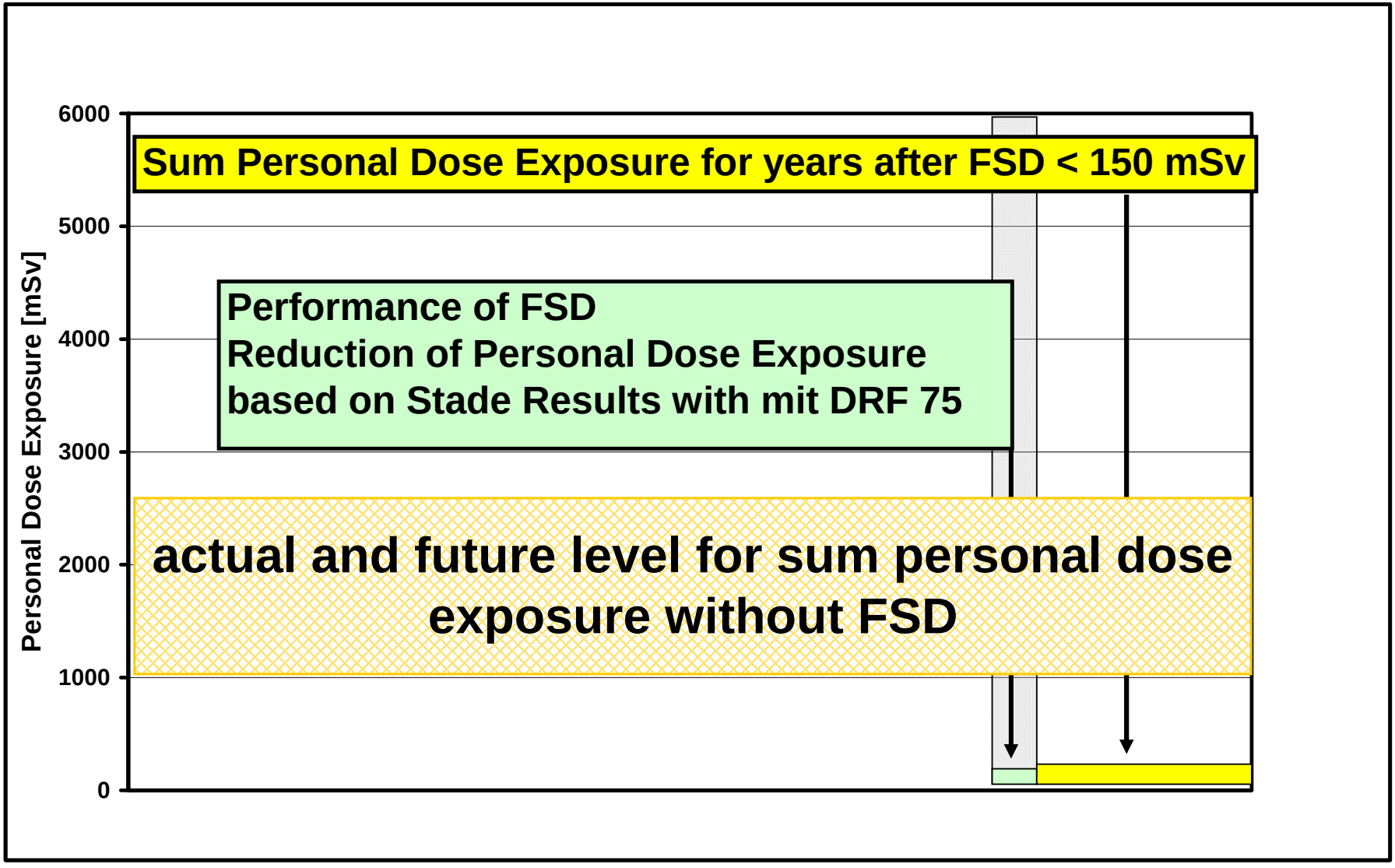
Personal Collective Dose with and without FSD
High Potential for Sustainable Dose Reduction and Savings



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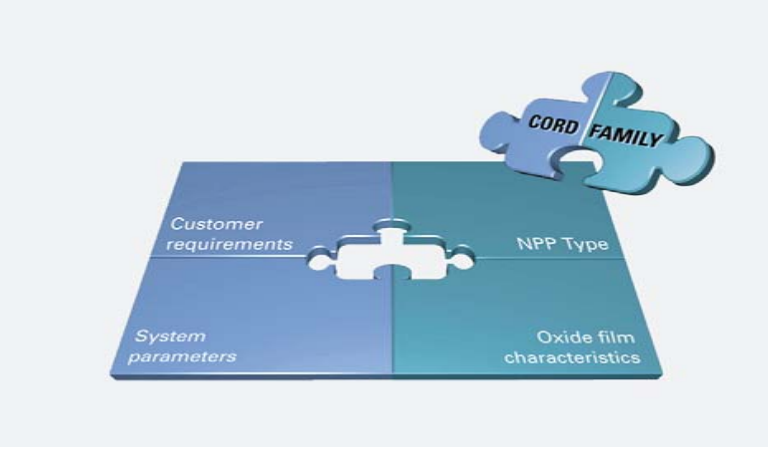
Concept for Sustainable Dose Reduction based on Proven Technologies

HP/CORD® UV



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FSD

- **Build up Protective Layer**
- **DZO (Depleted Zinc)**
- **Coolant Chemistry**
- **Shut down process**
- **particles removal**

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HP/CORD UV und AMDA
Proven and Reliable Decon Technology

1979 bis 1985	Development HP CORD UV & internal Siemens Qualification
1985	First RCP Decontamination in German PWR
1985-1986	Qualification TÜV Bayern
1986	First System Decontamination in German BWR
1988	Qualification TÜV Norddeutschland / TÜV Hannover
1987 bis 1994	150 System Decontaminations in Europe
1991	First PWR FSD for Decommissioning (BR3 Mol)
1993	First BWR FSD for Decommissioning (SWR, VAK)
1994	First FSDs in operating NPPs in BWR and PWR BWR, OKG 1 and PWR, Loviisa 2
1994 bis 1997	Qualification for Japan (all Designs) – MITI
1997 bis 2001	4 FSDs performed in Japan (BWR)
2004-2008	4 FSDs prior Decommissioning, 2 x PWR, KKS und KWO und 2 x BWR Barsebäck 1 und 2
2010	FSD PWR Grafenrheinfeld for operation
2011-2013	6 FSDs in preparation for operating NPPs (BWR & PWR) 1 FSD for Decommissioning

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References for FSDs in Operating NPPs

AREVA NP References:

Oskarshamn 1	1994	442 MWe, BWR, ABB, Sweden
Loviisa 2	1994	445 MWe, VVER, AEE, Finland
1 Fukushima 3	1997	760 MWe, BWR, GE/Toshiba, Japan
1 Fukushima 2	1998	760 MWe, BWR, GE/Toshiba, Japan
1 Fukushima 5	2000	760 MWe, BWR, Toshiba, Japan
1 Fukushima 1	2001	460 MWe, BWR, GE, Japan
Grafenrheinfeld	2010	1345 MWe, PWR, Siemens, Germany

AREVA NP References for FSDs prior to Decommissioning – Principle similar to FSDs in Operating NPPs

NPP	Country	Year	Design	OEM
BR3 MOl	Belgium	1991	PWR	WEC
VAK Kahl	Germany	1992/93	BWR	GE/AEG
MZFR Karlsruhe	Germany	1995	PWR, D_2O	Siemens KWU
Stade	Germany	2004/05	PWR	Siemens KWU
Obrigheim	Germany	2006/07	PWR	Siemens KWU
Barsebäck 2	Sweden	2007	BWR	ABB
Barsebäck 1	Sweden	2008	BWR	ABB

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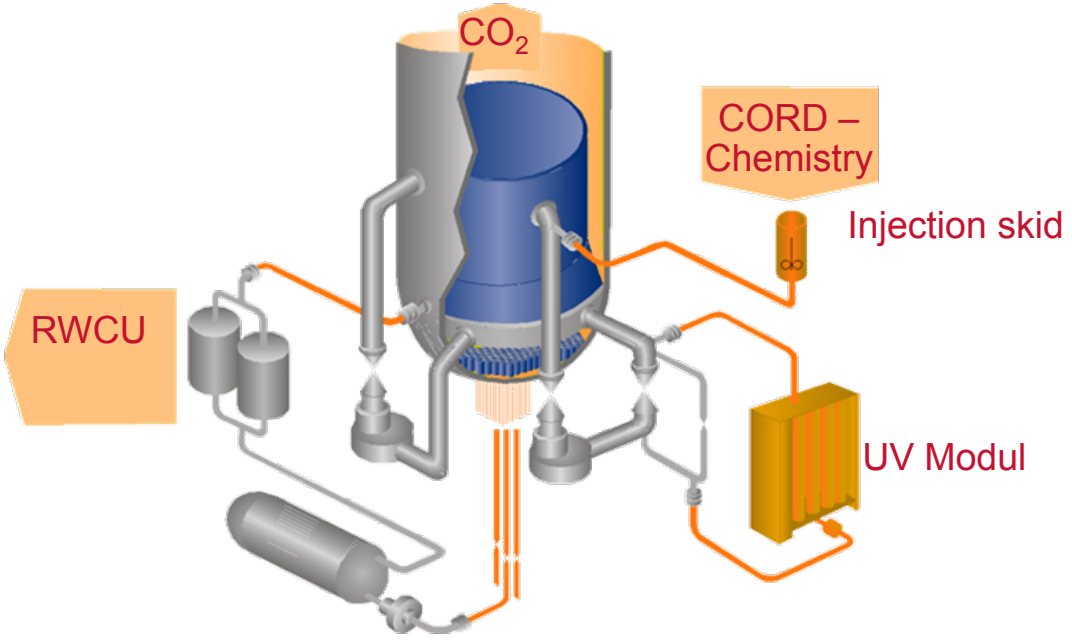
FSD OKG 1, 1994

2,3 E12 Bq Activity and 30kg corrosion products removed
IX-resin waste: 2,5 m³
Man-Rem Savings: 20000 mSv (customer data)
DF 20 upto > 1000; DRF > 10
Dose rate RPV bottom after FSD: 20 µSvh
Surface contamination < 4 Bq/cm²

RPV Inspection after Decontamination



Oskarshamn 1 – Decontamination Principle

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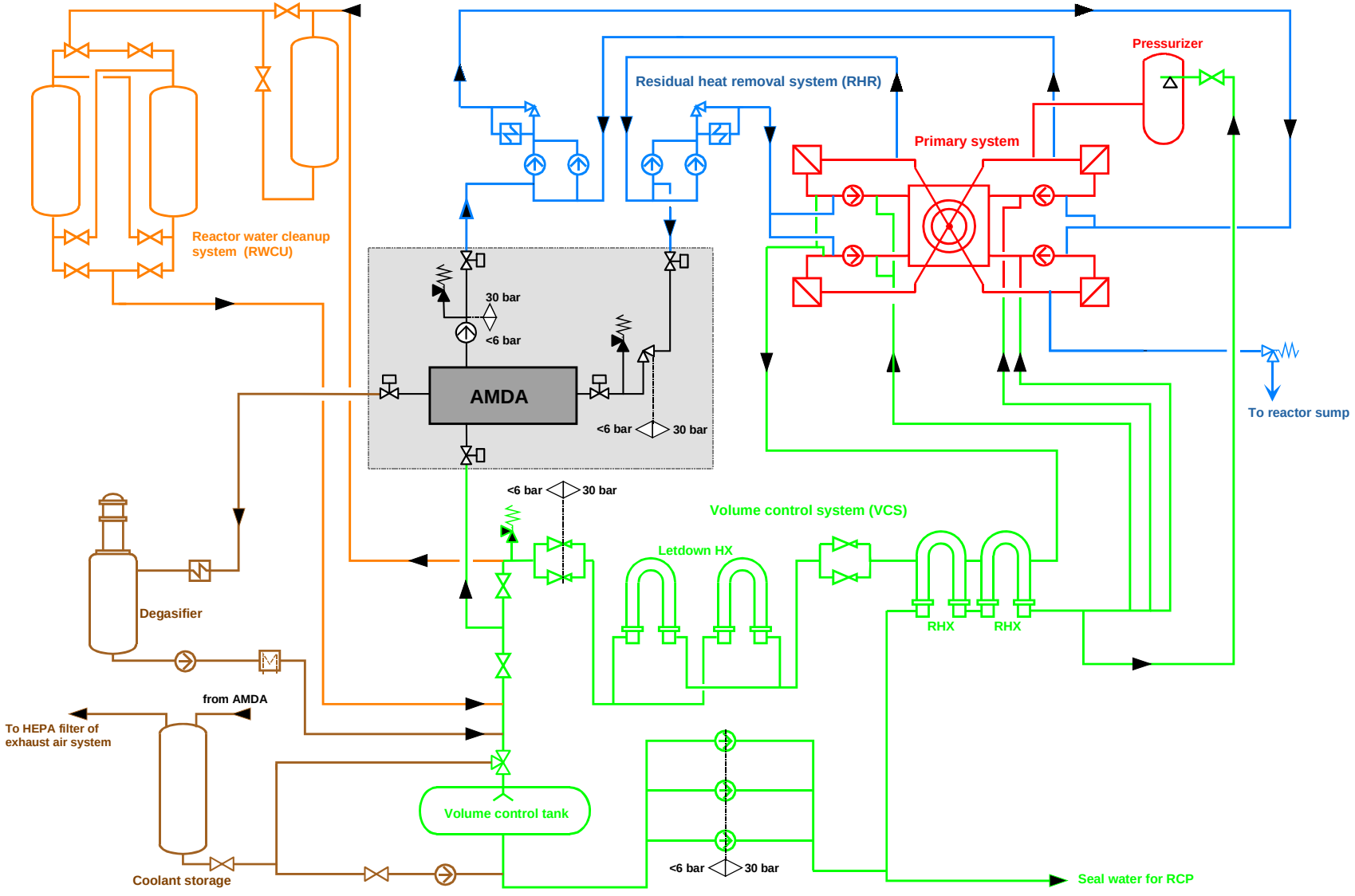
FSD in Siemens PWRs
Example FSD Stade prior Decommissioning



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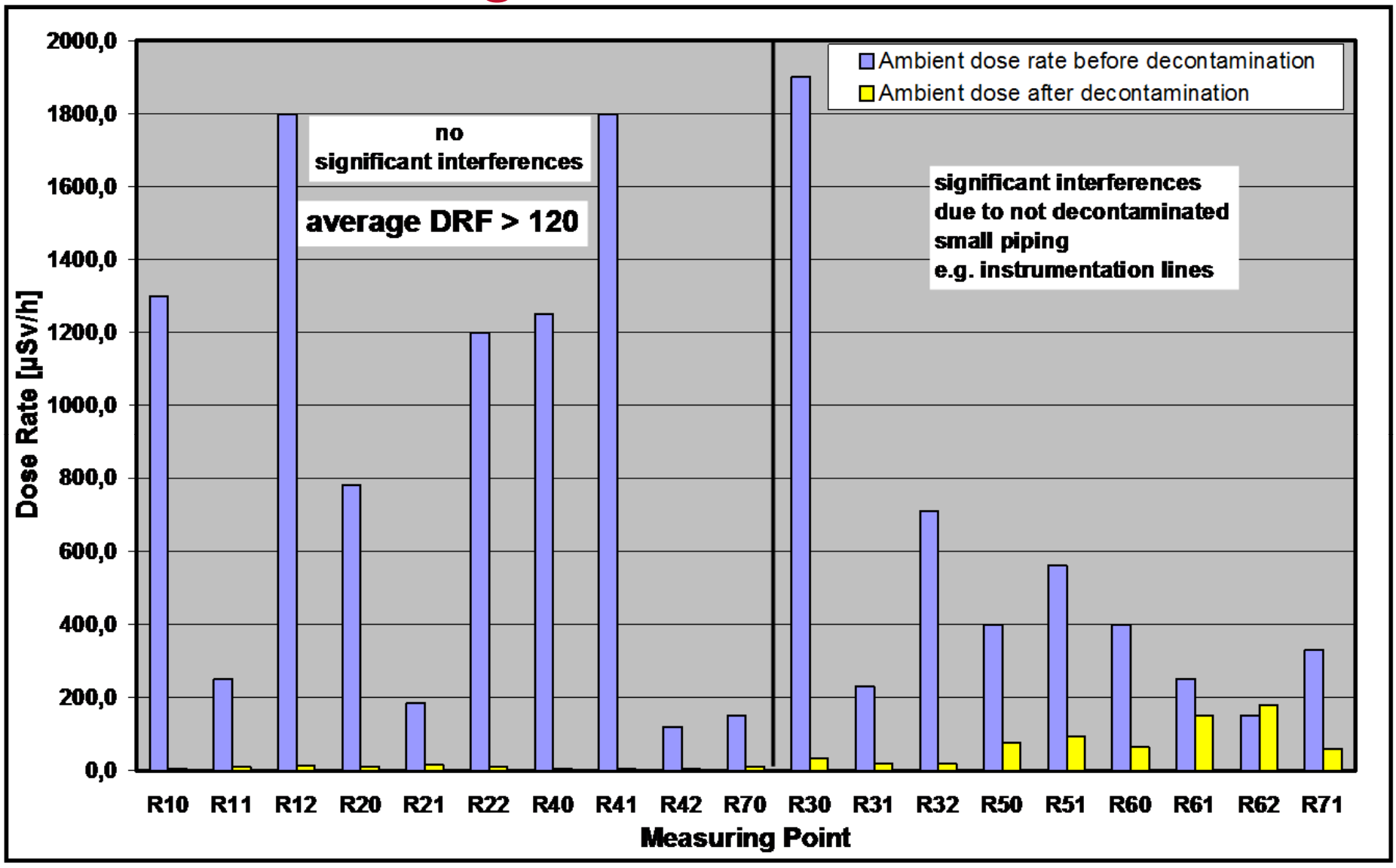
FSD Stade
High Ambient Dose Reduction



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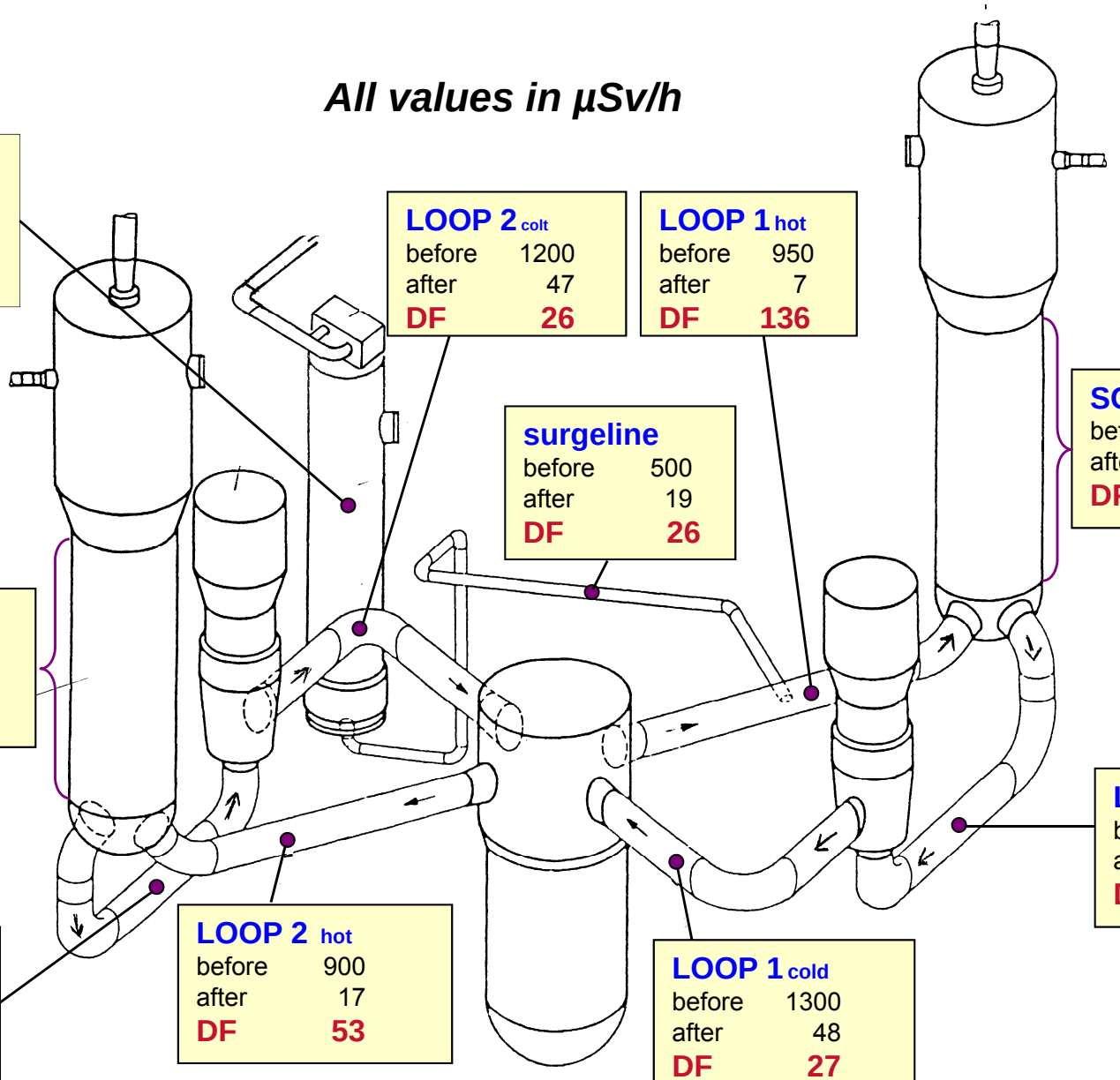
FSD Obrigheim
Excellent Dose Rate Reduction Values

All values in µSv/h



Pressurizer
before 70
after 5
DF 13

LOOP 2 colt
before 1200
after 47
DF 26

LOOP 1 hot
before 950
after 7
DF 136

SG 1 (MW 8 MP)
before 2300
after 1,6
DF 1597

surgeline
before 500
after 19
DF 26

SG 2 (MW 8 MP)
before 1900
after 1,6
DF 1220

LOOP 1
before 1000
after 34
DF 29

LOOP 2
before 1000
after 28
DF 36

LOOP 2 hot
before 900
after 17
DF 53

LOOP 1 cold
before 1300
after 48
DF 27

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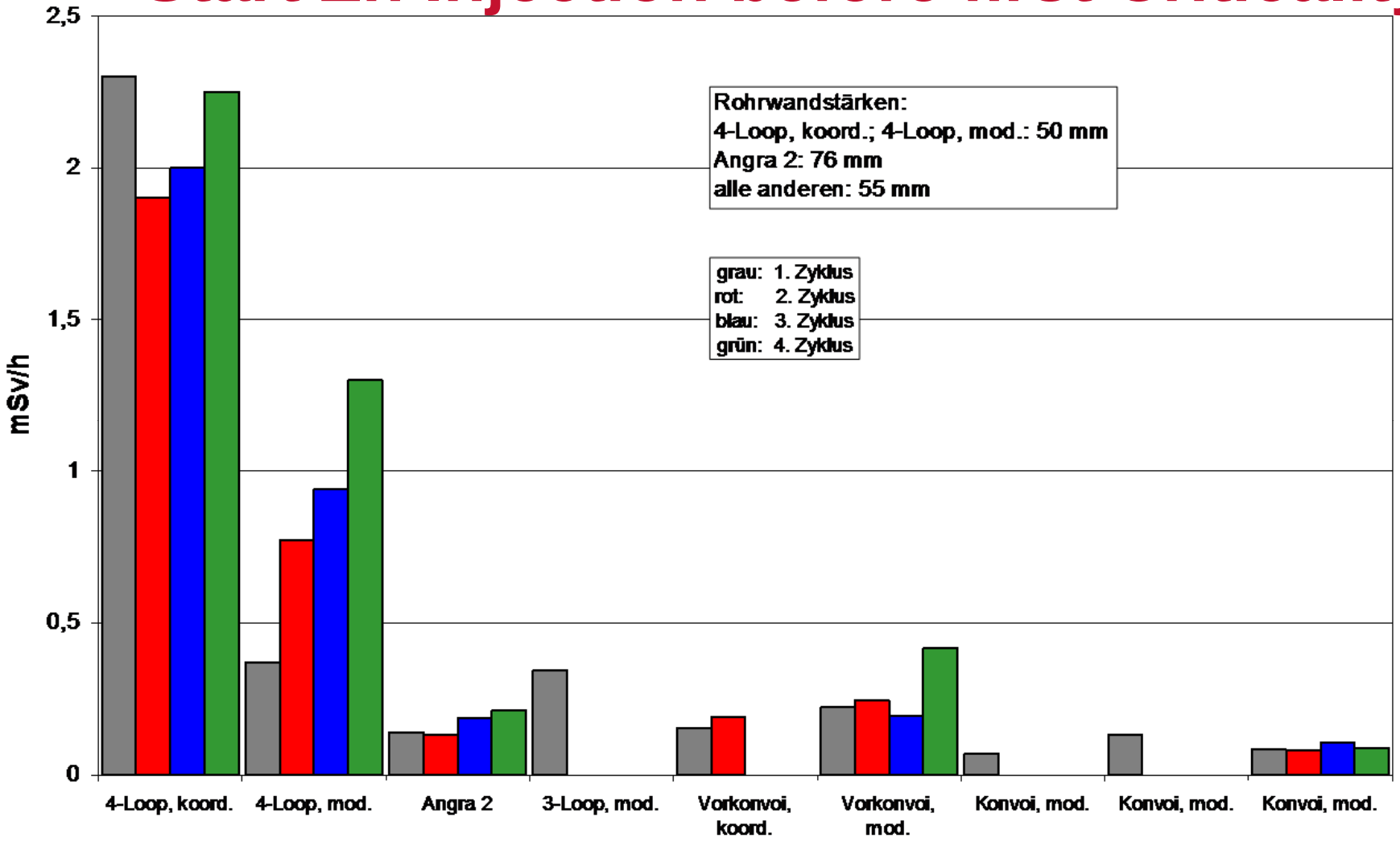
Results Zinc Injection
Start Zn Injection before first Criticality



Angra 2 Dose level today on low level, comparable with Konvoi NPPs

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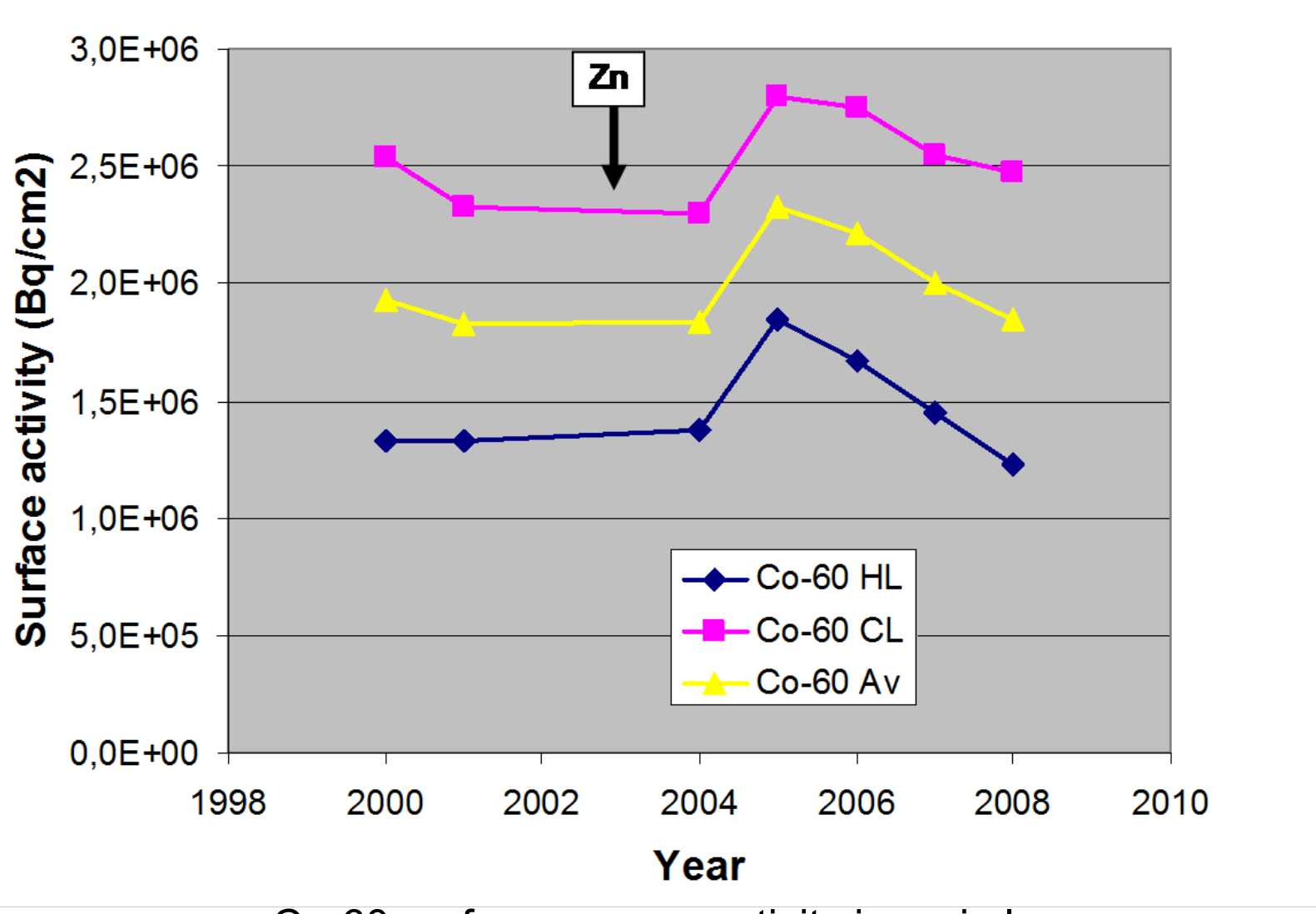
Results Zn Injection
Start Zinc Injection after Several Cycles



Co-60 surface gamma activity in main loops

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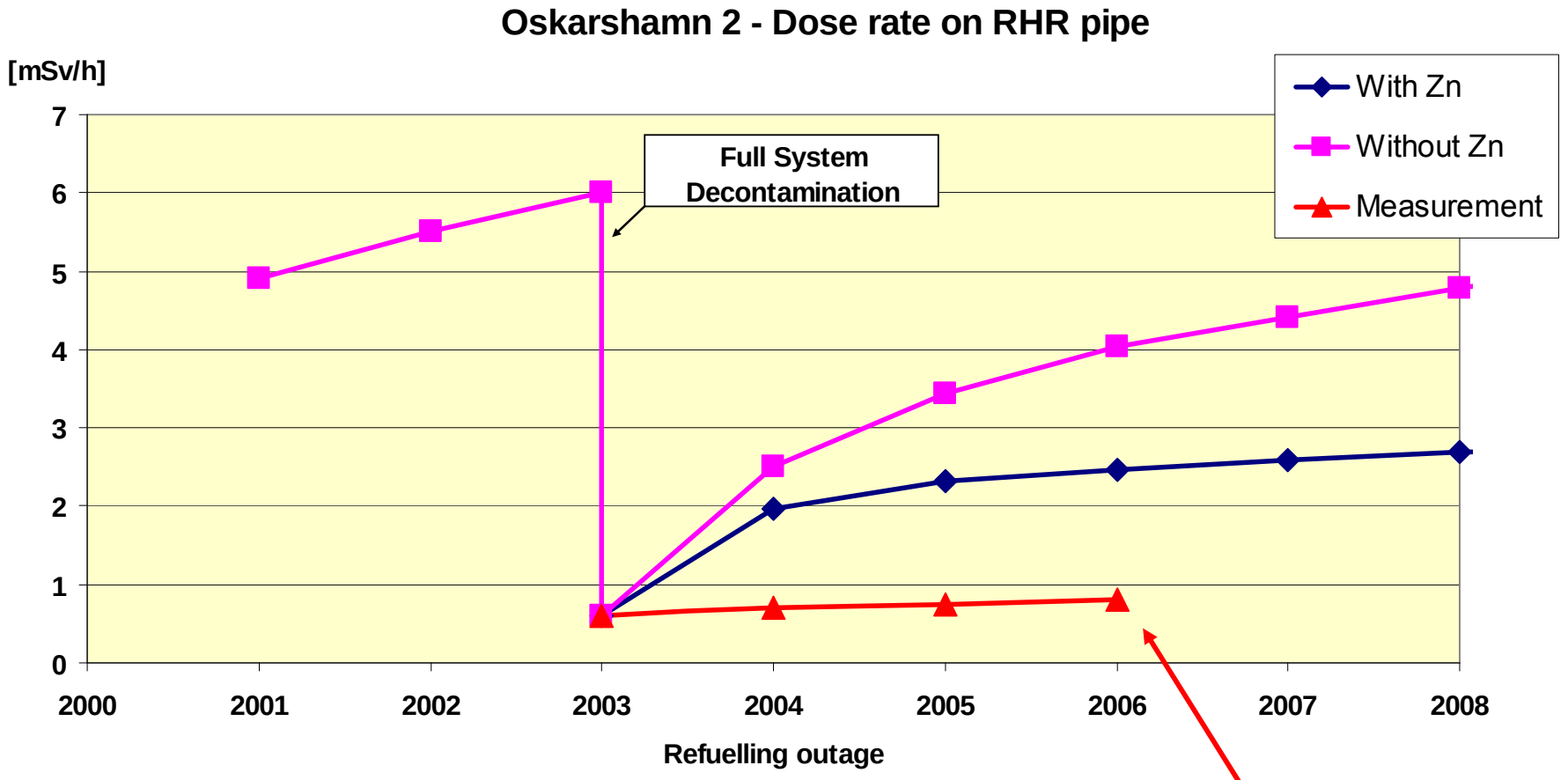
Example for Decontamination and Zn-Injection Sustainable Dose Reduction



Ref: Johan Lejon, Hamaoka, Japan, 2006

Reality, measured dose rates much lower than estimates

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Summary
AREVA NP Concept for Sustainable Dose Reduction

- **Concept is basing on proven technologies**
  - **HP/CORD UV**
    - References
    - Material compatibility
    - Low waste volumes
  - **AMDA**
    - Proven and reliable technology since more than 30 years
  - **FSD**
    - Experiences and development for FSDs for decommissioning
    - References for FSDs in operating NPPs without negative experience during the following cycles (e.g. OKG 1 and Loviisa 2 now > 10 years in operation after FSD)
    - System integrity
- **Protective Layer build up**
  - **References of new builds and for SG replacement**
- **Zn-Injection (DZO)**
  - **References**
    - Before first criticality: NPP Angra 2
    - Implementation after several cycles: worldwide operating NPPs

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