Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Swiss Confederation
Swiss Federal Nuclear Safety Inspectorate ENSI

Kernkraftwerk
Leibstadt

Filtered Containment Venting Systems

at

Swiss NPPs

and

KKL in particular

January 15, 2014, Ft. Lauderdale

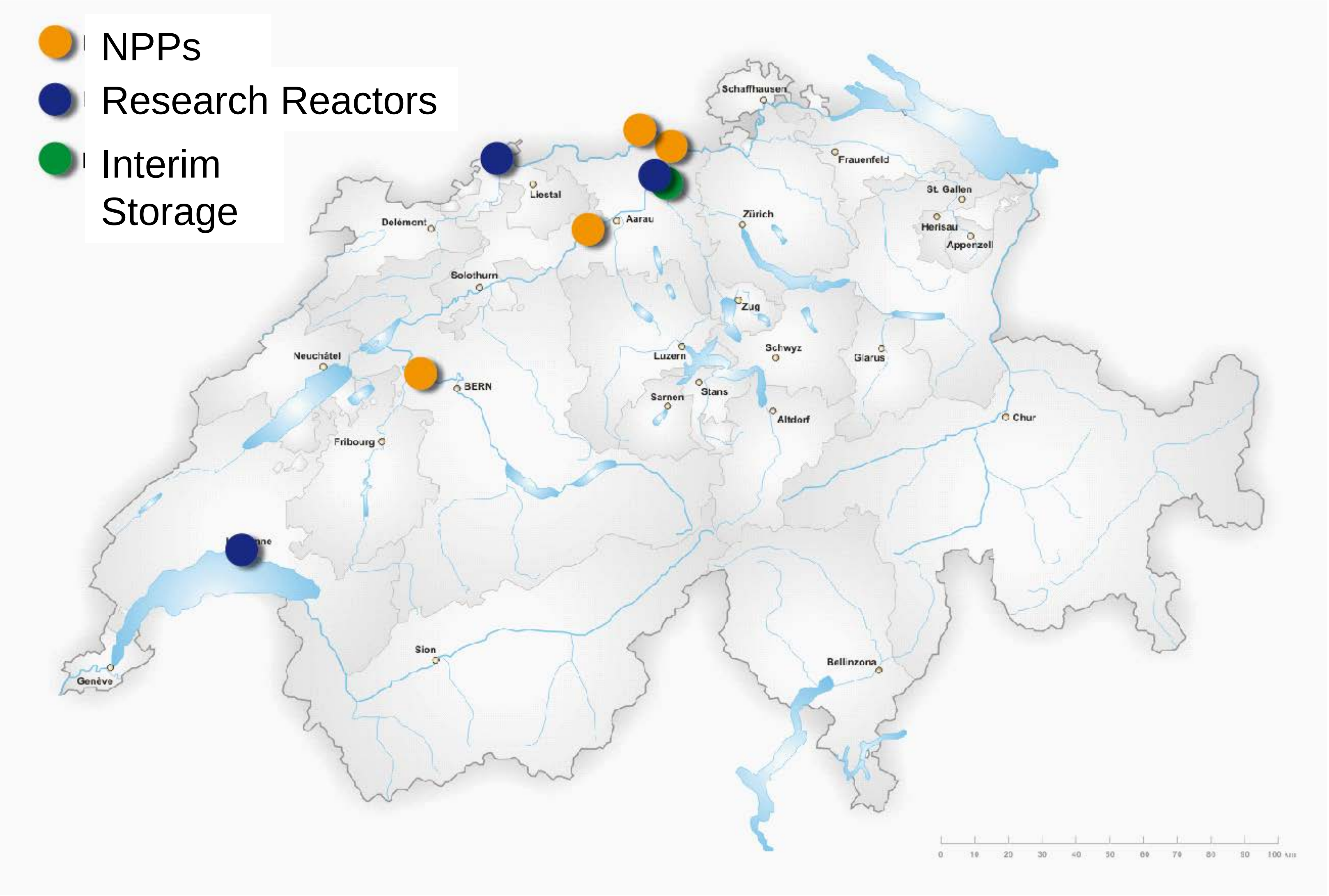
J. Hammer, ENSI, and A. Ritter, KKL

Agenda

- Swiss Nuclear Power Plants
- Filtered Containment Venting Systems (FCVS)
- Current Venting Systems in Swiss NPPs KKB, KKG and KKM
- The FCVS at Leibstadt NPP

The four Swiss NPPs

Nuclear Installations in Switzerland



Mühleberg Nuclear Power Plant (KKM)

BWR

Start of commercial operations:

1972

Net electrical output:

355 MW_{el}

End of operations scheduled for 2019

Gösgen Nuclear Power Plant (KKG)

Copyright KKG

PWR

Start of commercial operations:

1979

Net electrical output:

985 MW_{el}

Beznau Nuclear Power Plant (KKB 1 & 2)

PWR

Start of commercial operations:

KKB 1: 1969

KKB 2: 1971

Net electrical output:

380 MW_{el} each

Leibstadt Nuclear Power Plant (KKL)

Copyright KKL

BWR

Start of commercial operations:

1984

Net electrical output:

1220 MW_{el}

May 2011: **No nuclear new build!**

Filtered Containment Venting

Philosophy of Filtered Containment Venting

i. Filtered Containment Venting (FCVS) is a measure for beyond design basis accidents.

ii. The FCVS is in general passive and does not depend on any external input such as actuation, mechanical movement or supply of power.

iii. The FCVS is important to safety;
its malfunction could lead to radiation exposure of members of the public.

iv. The FCVS serves mitigate the consequences of a severe accident.

v. IAEA NS-G-1-10, 4.143 says: Where containment venting systems are installed, the discharge should be filtered to control the release of radionuclides to the environment. Typical filter systems include sand, multi-venturi scrubber systems, HEPA or charcoal filters, or a combination of these. HEPA, sand or charcoal filters may not be necessary if the air is scrubbed in a water pool.

vi. In case of a severe accident we have to deal with wet and hot gas and air mixtures. Therefore, the FCVS must resist temperatures up to 160°C and high vapor concentration.

vii. The important nuclides are ^{131}I, ^{134}Cs and ^{137}Cs.

viii. The FCVS should be designed for heat removal of several MW_{th} during 3 to 5 days

New Guidelines for FCVS (ENSI, preliminary)

- The FCVS is a Safety Relevant System
- In addition to the FCVS, ENSI demands a passive ventilation system without operator action
- The FCVS is always ready during power operation
- Remote and Local operation, RP-conditions
- Simple and passive design, no AC power need
- The gas flow has to be adjustable
- Exhaust via stack, two valve closing system
- Exchange of water and chemicals in the filter during operation should be possible

Design Basis for FCVS (ENSI, preliminary)

- Retention factor >1000 for aerosols
  >100 for elementary Iodine
  to be proven by experiments in the range of 30 to 100% of nominal flow
- Filter loading up to 150 kg aerosols
- Probability for containment rupture < 0.1%
- Operating time >100 hours, self-sufficient
- Earthquake resistant as the containment building
- Resistant to pressure peaks
  as in case of hydrogen deflagration

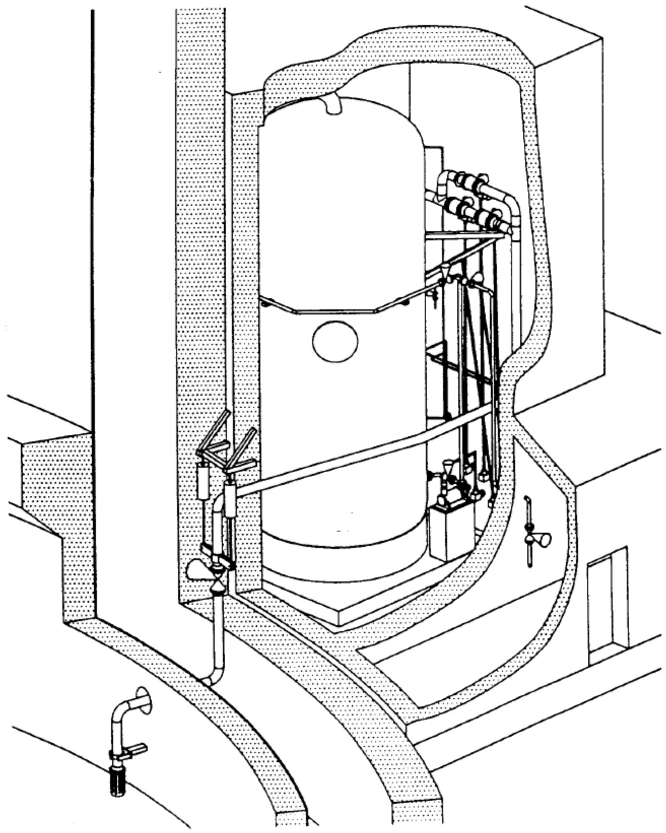
Venting Systems at Swiss NPPs

SIDRENT
the FCVS of KKB 1 & 2

Technical Data

max. containment pressure: 3.1 bar nominal,
6.2 bar break down
Rupture Disk nominal pressure: 4.2 bar
Nominal flow rate: 4.5 kg/s
Filter: Air-Lift-Effect
Diameter: 3.5 m
Height: 7 m
water capacity: 30m^3
max. Filter loading: 150 kg
max. Temperature: 166°C
Retention factor: >1000 for aerosols
>100 for Iodine (elementary)
Self-sufficient operating time: 24 h

SIDRENT
the FCVS of KKB 1 & 2



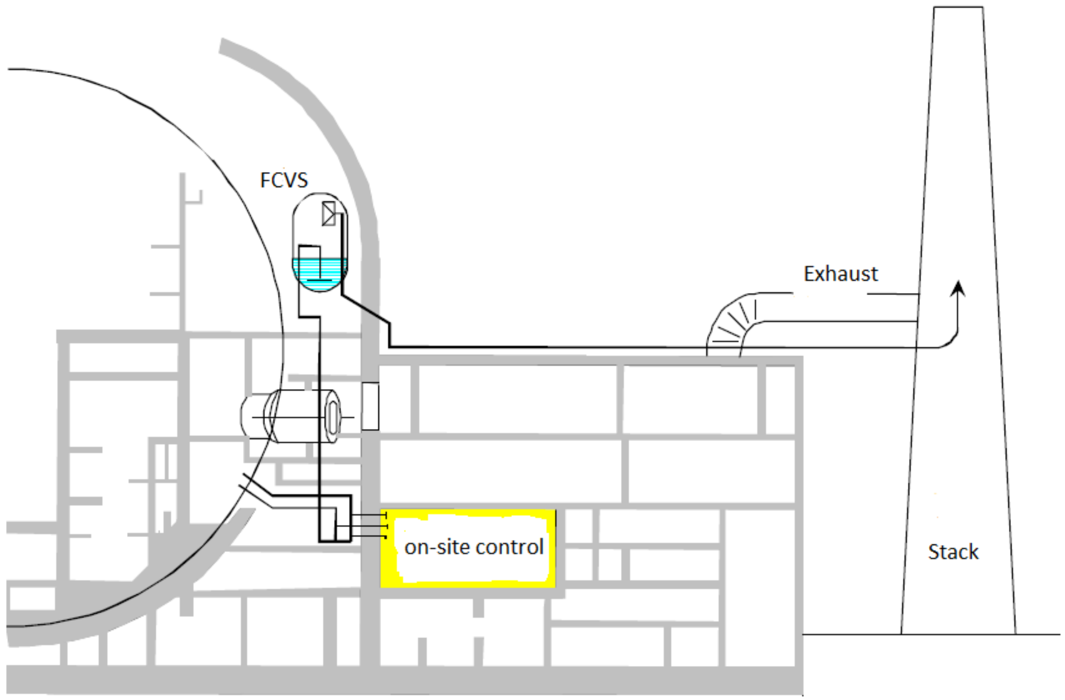
KKG Filtered Containment Venting

Technical Data

max. containment pressure: 5.89 bar abs. nominal,

Rupture Disk nominal pressure: 6.5 bar
Nominal flow rate: ~2 m^3/s
Filter: Venturi Scrubber System
Diameter: 3.0 m
Height: 6.0 m
water capacity: 15 m^3
max. Filter loading: 200 kg
max. Temperature: 160°C
Retention factor: >1000 for aerosols
>100 for Iodine (elementary)
Self-sufficient operating time: 24 h

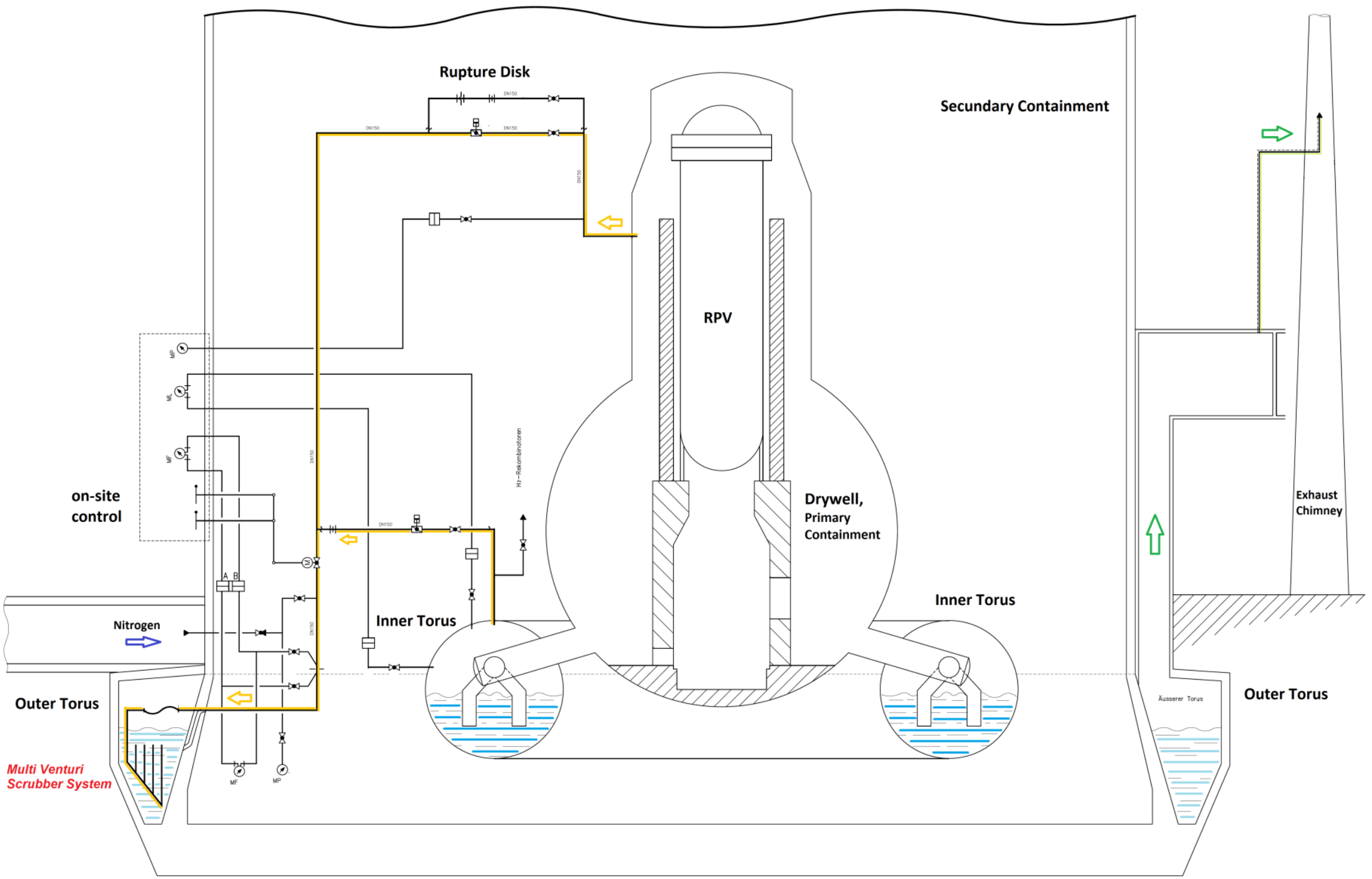
KKG Filtered Containment Venting Scheme



KKM Filtered Containment Venting CDS

- Technical Data
- max. containment pressure: 9.5 bar
- Rupture Disk nominal pressure: 6.2 bar
- Nominal flow rate: 25 kg/s
- Filter: Multi Venturi Scrubber System
- Outer torus water capacity: 1000m^3
- Retention factor: >1000 for aerosols
- >100 for Iodine

KKM - CDS



Rupture Disk
Secundary Containment
RPV
on-site
control
Drywell,
Primary
Containment
Inner Torus
Inner Torus
Exhaust
Chimney
Nitrogen
Outer Torus
Outer Torus
Multi Venturi
Scrubber System

KKL-FCVS

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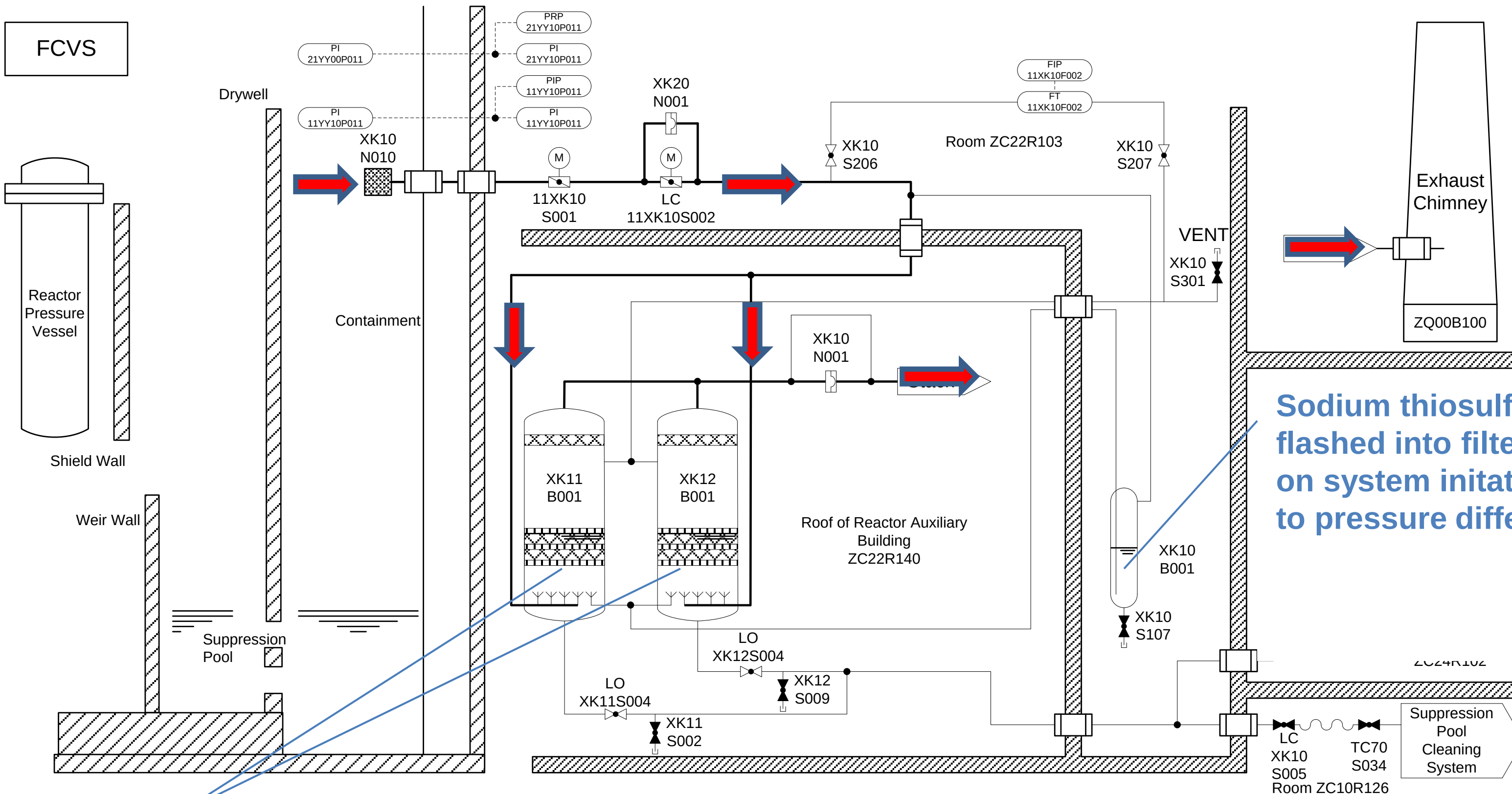
Actual Filtered Containment Venting System

- Layout
- Efficiency
- Radiological Impact

Planned Improvements

- Hydrogen Problem
- Radiation Monitor
- Filter Long Term Retention

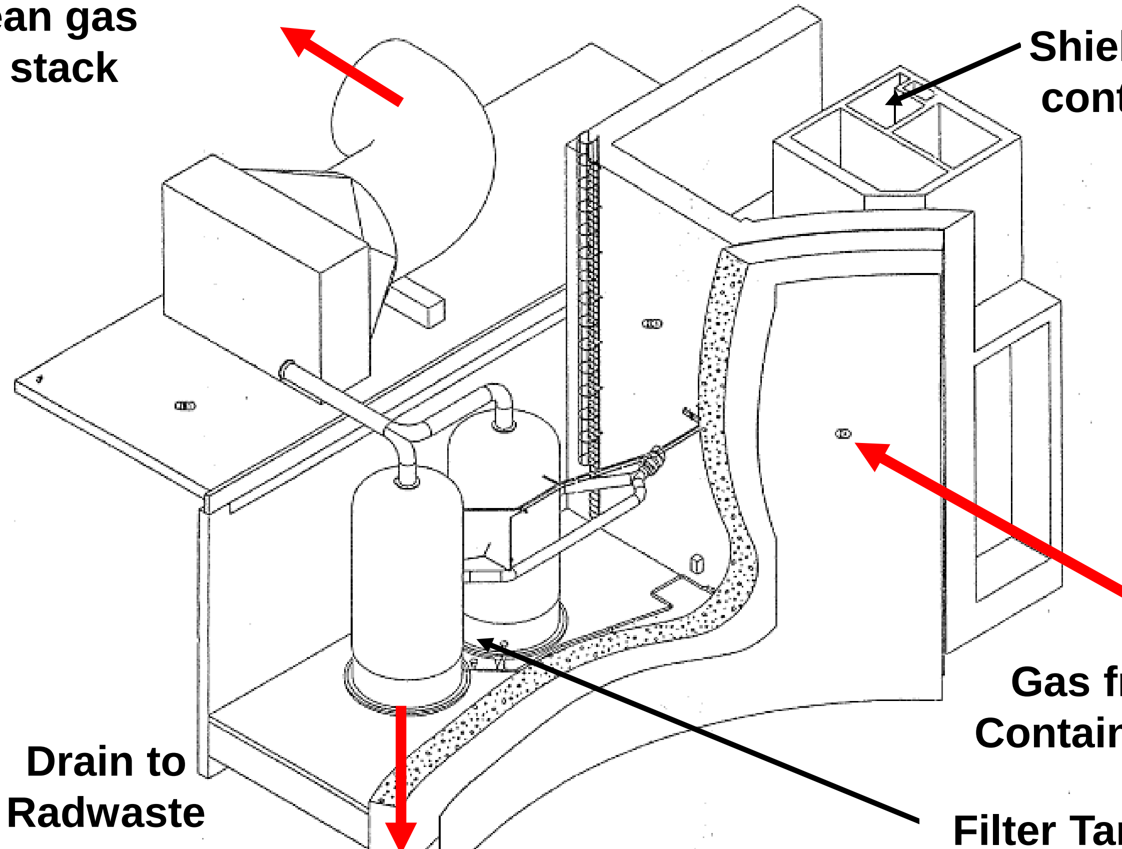
Filtered Containment Venting System Scheme



Sodium thiosulfate is flashed into filter tanks on system initation due to pressure difference

- Scrubber construction ensures 5 sec residence time allowing for Iodine reaction to complete
- 12 radial branches equipped with nozzles (92 nozzles per filter) expand the gas-steam mixture into aerosol-carrying bubbles

Layout



Designer: Sulzer / EWI

Rupture Disc Pressure [bara]**:** 3.1

Operating Pressure [bara]**:** 2.55

Comissioning: 1993

Max Flow [kg/s]**:** 20.66

Nominal flow [kg/s]**:** 13.77

FCVS Efficiency

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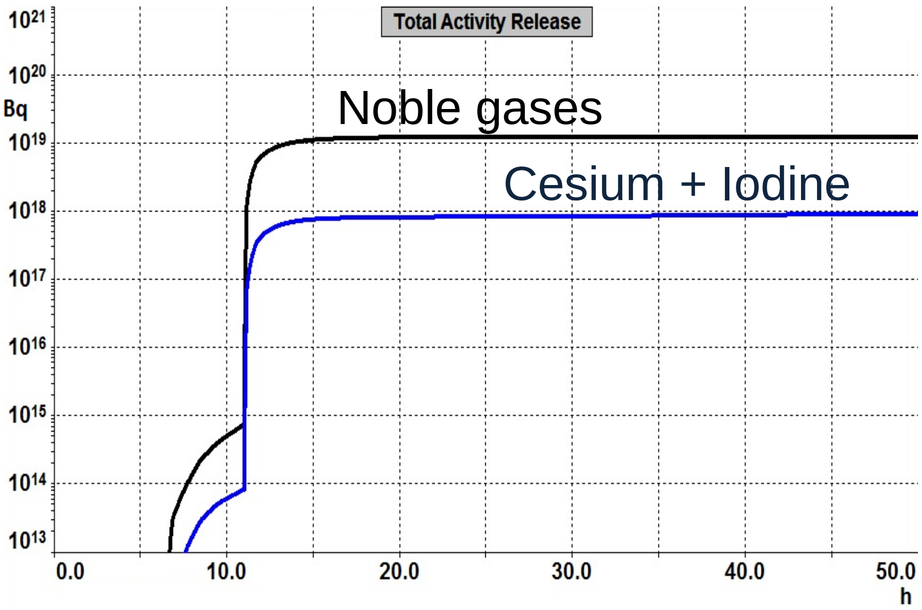
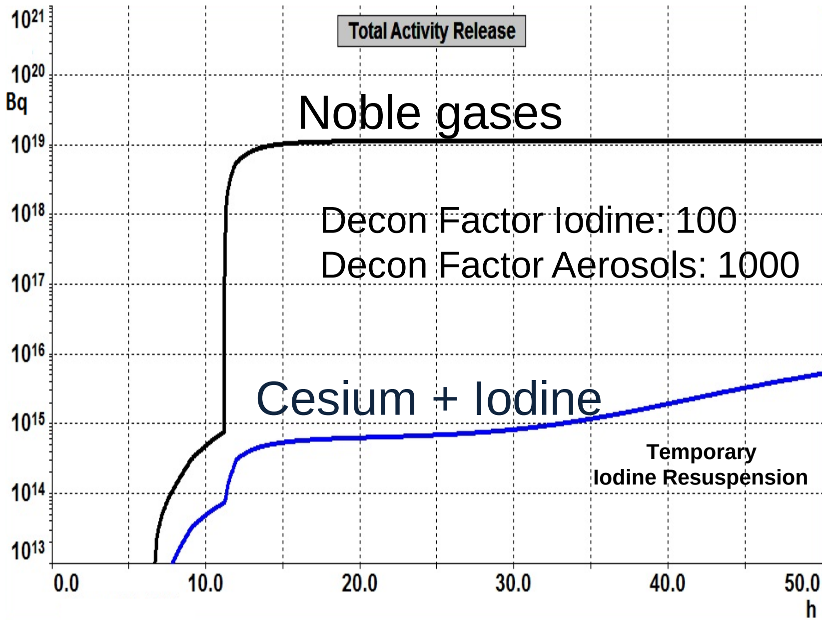
Activity release ("source term") after postulated core melt accident

Without Filter ("Fukushima")

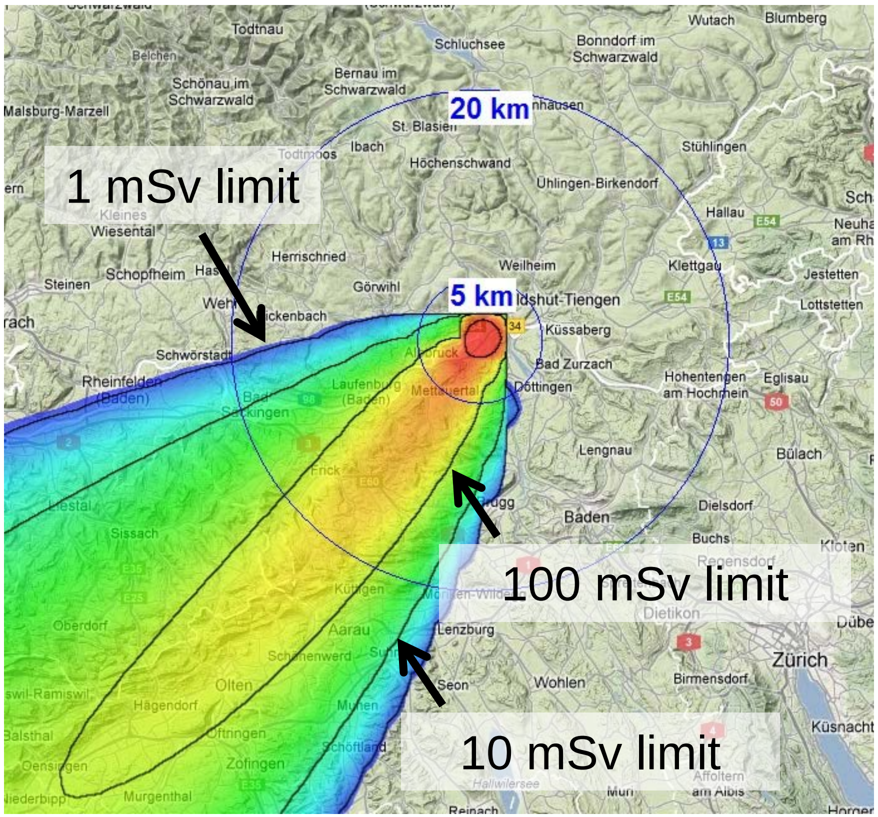


With FCVS Filter ("KKL")

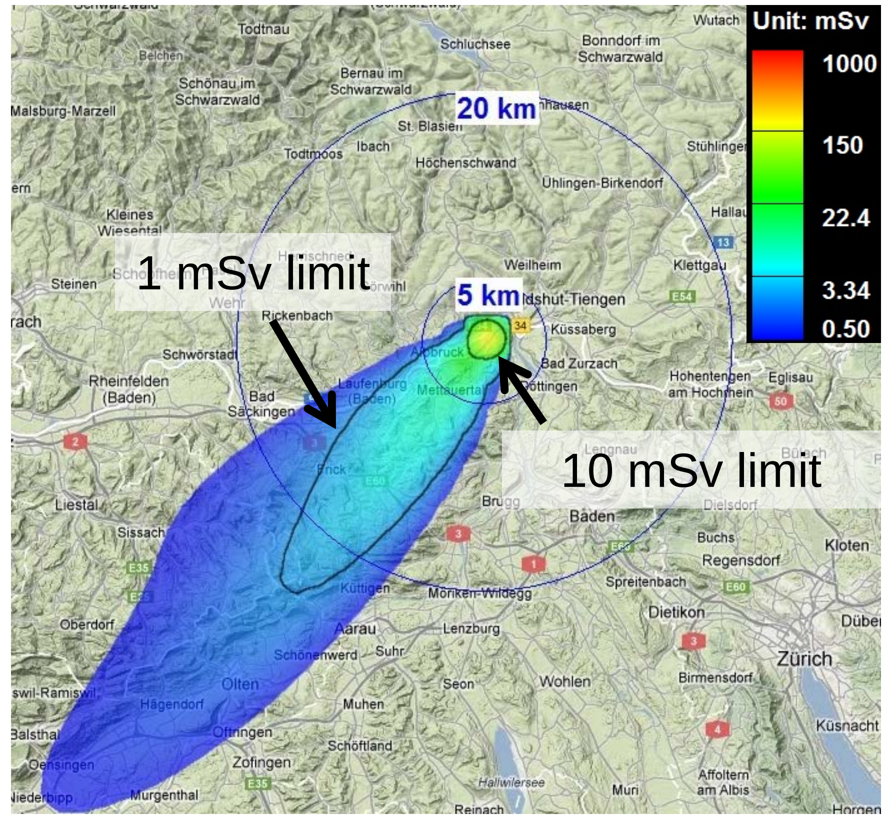


Simulation: 1 Year Committed Dose

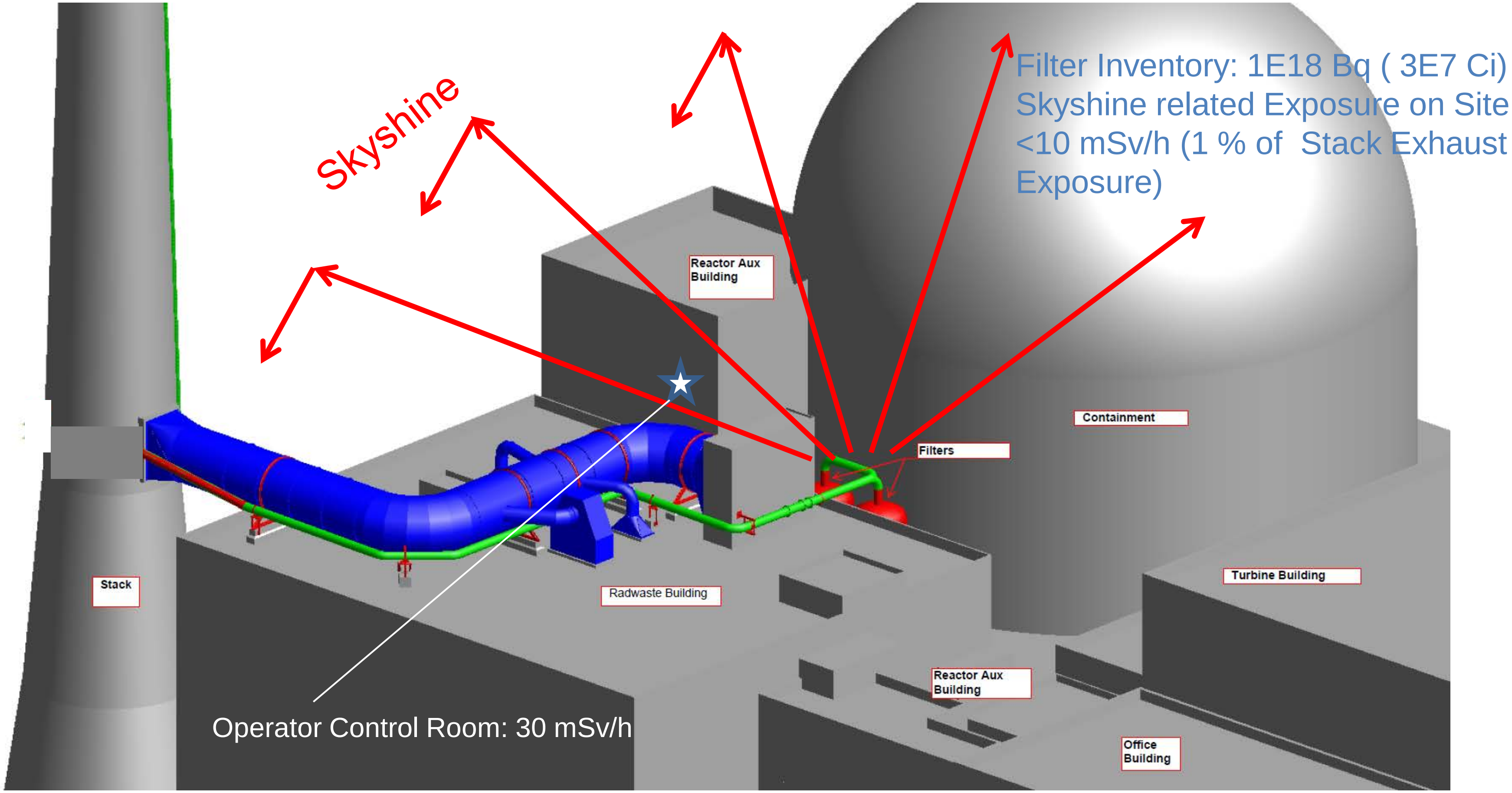
Without Filter (“Fukushima”)



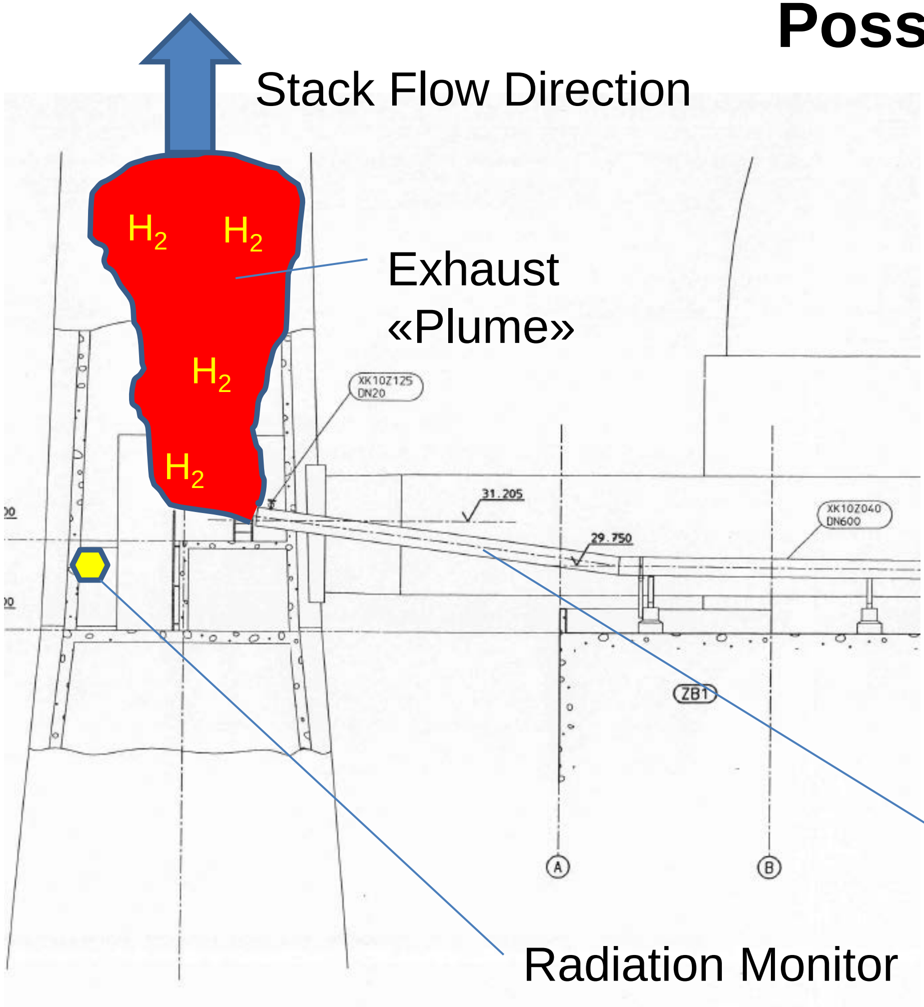
With FCVS Filter (“KKL”)



Radiological Impact of Loaded Filters: Direct radiation very well shielded by



Problems with Existing Configuration: Possible Hydrogen Explosion

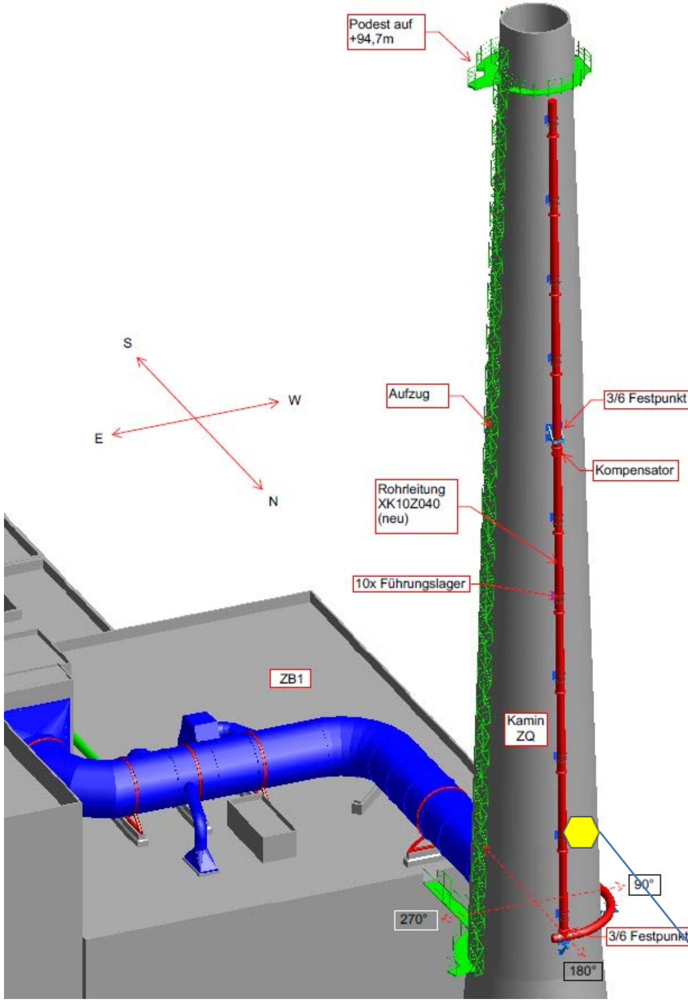


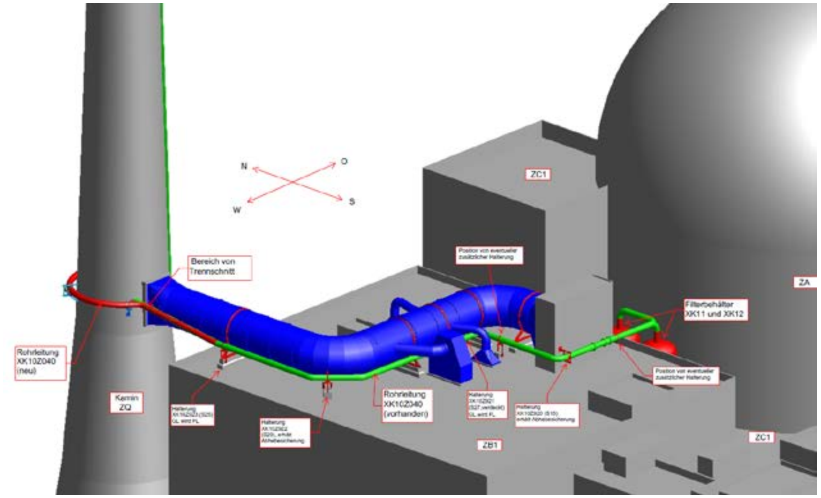
- Hazard of Explosion due to Hydrogen Input into Stack
- Calibration of Rad Monitor not easy due to difficult Geometry

Difficulties with Source Term Estimation

- Sampling not possible, very high Dose Rates of Samples and inside Stack
- Radiation Monitor is measuring Dose Rate [mSv/h], resp. [R/h]
- Conversion Factor Dose Rate to Source Term
  - [mSv/h] ⇨ [Bq/h], resp. [R/h] ⇨ [Ci/h]
  - Conversion Factor is depending on Energy of Nuclide-Mixture and Stack Ventilation Rate: Depending on Accident Conditions and elapsed Time (rad. Decay).
  - Conversion Factor is averaged for many different Accident Conditions over first 8 hours: 5E11 ($Bq \cdot h / Sv \cdot m^3$)
  - Stack Flow my be not well defined under Accident Conditions
- Radiation Monitor needs to be relocated

New Pipe Routing outside Stack, new Rad Monitor Location





- No Hydrogen Input into Stack:
  No Explosion Hazard
- New Location of Rad Monitor (inside or outside of Stack Wall)
- Easy Calibration due to well defined Geometry

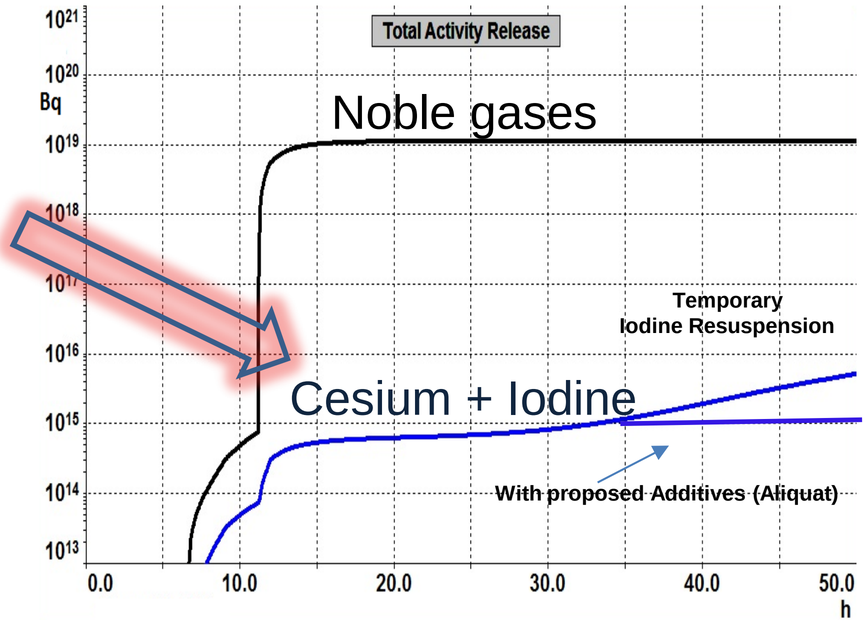
Radiation Monitor

Filter Long Term Retention

Activity release ("source term") after postulated core melt accident

Change in Filter Chemistry under Consideration:
Long Term Retention of Organic Iodine (CH_3I) possible

With FCVS Filter ("KKL")



Conclusions

- Filtered Containment Venting System were implemented 20 years ago in all Swiss NPP
- FCVS turned out to be very helpful in the Post-Fukushima Safety Evaluations
- Improvements concerning Hydrogen, Earthquake Resistance, and Source Term Evaluation under way

for more information please visit:

www.kkl.ch

www.ensi.ch

www.ifsn.ch

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