Tellurium transport in the primary circuit of a nuclear power plant (NKS-R TETRA)

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WHY TELLURIUM?

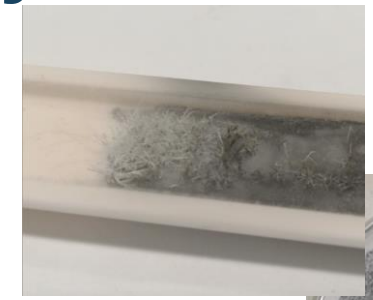
- Releases from Fukushima and Chernobyl comparable to those of iodine and cesium

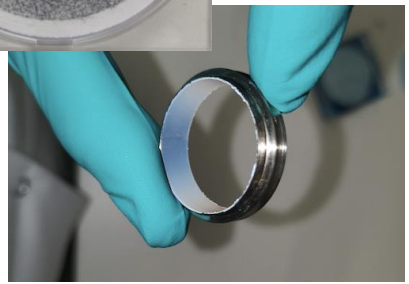
- Tellurium is one of the most significant radionuclides released during a nuclear accident
  - Volatile
  - Relatively long-lived isotopes
  - Somewhat chemically toxic
  - Decays to iodine

- So far, the release and behavior of tellurium in the core are well known but the transport to and behvaior in the containment are unclear

Experimental SA chemistry

- Experimentalists are a rare species nowadays
- Large facilites used in e.g. PHEBUS, VERCORS expensive
- Small-scale and detailed experiments still needed
- Managements systems like pool scrubbing and re-volatilization studies popular
- Important in developing codes and incorporating chemistry

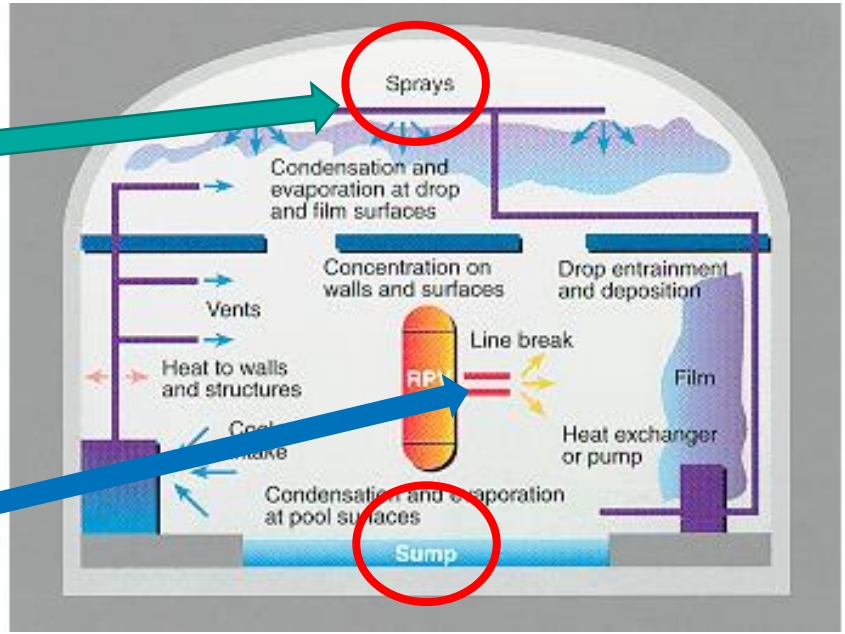




Focus of TETRA project

Removal of tellurium species by the **containment spray system**

Transport of tellurium species in the **Reactor Coolant System (RCS)**

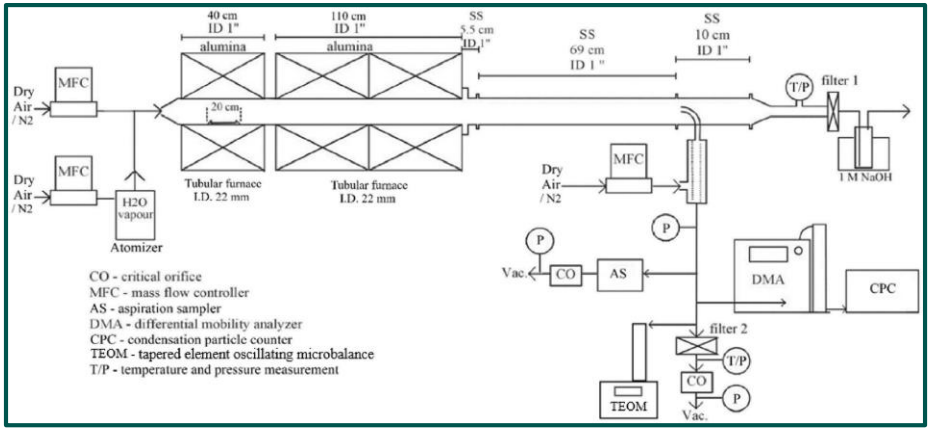


http://www.nucleartourist.com/systems/cs.htm

Experimental: Transport of Tellurium

How does atmosphere, humidity and other fission products affect tellurium transport?

- Six experiments conducted with changing parameters
- Air and nitrogen used as carrier gases
- Temperature chosen to represent RCS conditions
- Aerosol size and amount, particulate/gaseous species and precursor were analyzed

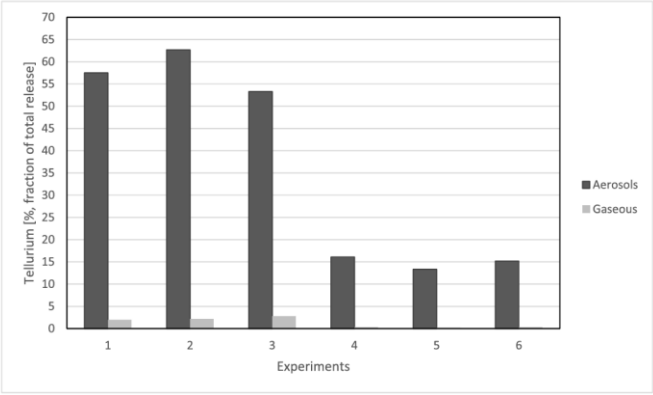


Condition	Experiment	Gas	Temperature[a] [K]	Humidity [ppmV]	Caesium iodide [M][b]
Oxidizing	1	Air	1500	Dry	
	2	Air	1500	$2.1 \cdot 10^4$	
	3	Air	1500	$2.1 \cdot 10^4$	0.15
Inert	4	Nitrogen	1500	Dry	
	5	Nitrogen	1500	$2.1 \cdot 10^4$	
	6	Nitrogen	1500	$2.1 \cdot 10^4$	0.15

[a] Temperature in the reaction furnace.
[b] Concentration of the solution used in the atomizer.

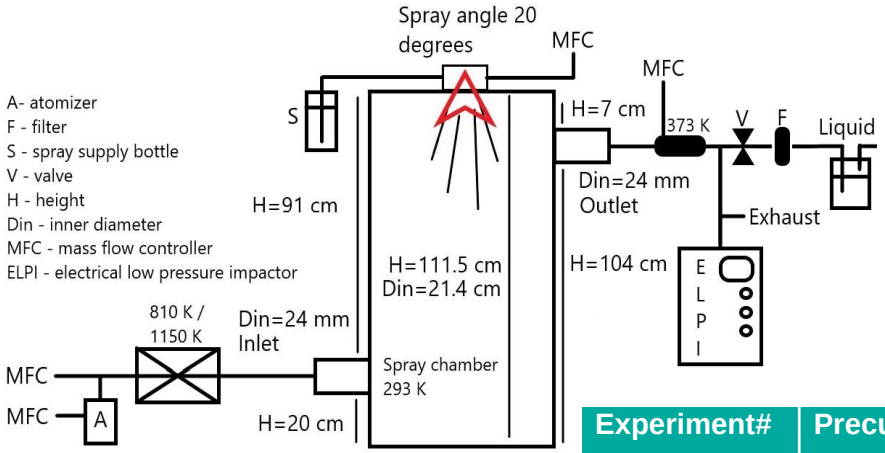
Results: Transport of Tellurium

- Majority of tellurium was transported in particualte form (aerosols), only small percentage as “gaseous”
- Humidity increased the amount Te **in air** → Supported by the literature
- Slight decrease in transport when CsI added **in air**
- Significantly lower release in inert (N_2)
- No unexpected species observed



Condition	Experiment	Te-aerosols (filter)	Te-gaseous (liquid traps)	Identified species	Agglomerated chains
Oxidizing	1	58%	2.0%	TeO_2	Thin dendritic structure (<100)
	2	63%	0.95%	TeO_2	
	3	50%	0.71%	TeO_2, TeO_3, CsI	
Inert	4	16%	0.99%	TeO_2, Te	Chains of spherical particles (<50)
	5	13%	0.57%	TeO_2, Te	
	6	15%	0.94%	TeO_2, Te, CsI, Cs, I	

Experimental: Containment Spray System



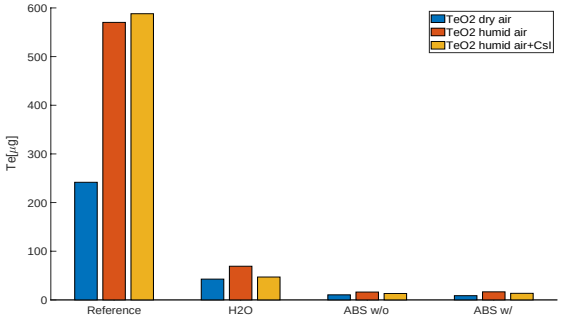
- **Removal efficiency towards tellurium species formed under various conditions**
- **Effect of chemical composition of the spray**

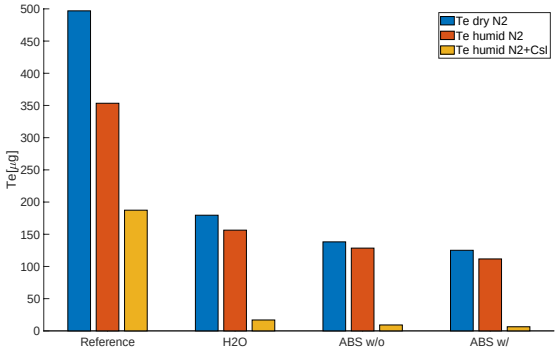
Spray solutions used:

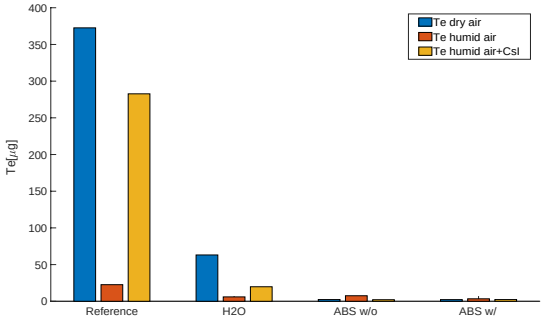
- Water
- Alkaline borate solution (ABS) without sodium thiosulfate
- Alkaline borate solution (ABS) with sodium thiosulfate

Experiment#	Precursor	Temperature, [K]	Atmosphere	Added humidity	CsI
1	TeO_2	1150	Air	No	
2	TeO_2	1150	Air	Yes	
3	TeO_2	1150	Air	Yes	Yes
4	Te	810	Air	No	
5	Te	810	Air	Yes	
6	Te	810	Air	Yes	Yes
7	Te	810	Nitrogen	No	
8	Te	810	Nitrogen	Yes	
9	Te	810	Nitrogen	Yes	Yes

Results: Removal Efficiency







	Removal Efficiency [%]		
Experiment	MilliQ water	ABS without thiosulfate	ABS with thiosulfate
1	83	96	97
2	89	97	97
3	91	97	97
4	83	99	99
5	74	73	73
6	92	99	99
7	63	72	75
8	70	65	60
9	89	93	94

What can we learn form these results?

- **Tellurium transport in the RCS** is affected at least by atmosphere and humidity
  - Humidity increases the Te transport in air due to formation of more volatile species
  - Transport lower in N2 atmosphere
  - No new species formed in any of the experiments, transient/intermediate species possibly not detectable
  - *Espegren, F., Kärkelä, T., Pasi, A. E., Tapper, U., Kučera, J., Lerum, H. V., ... & Ekberg, C. (2021). Tellurium transport in the RCS under conditions relevant for severe nuclear accidents. Progress in Nuclear Energy, 139, 103815.*

- **Containment spray system** is efficient in removing tellurium species
  - Addition of CsI increased the removal due to agglomeration
  - Removal in nitrogen atmosphere was slighty lower → Shift in particle size distribution
  - Chemical effect considered negligible
  - *Kärkelä, T., Pasi, A. E., Espegren, F., Sevón, T., Tapper, U., & Ekberg, C. (2021). Tellurium retention by containment spray system. Annals of Nuclear Energy, 164, 108622.*

Current and future work on tellurium

- Tellurium behavior in the containment sump
- Organic tellurium chemistry → Formation of volatile species
- Management of these possible re-volatilized species e.g. scrubber efficiency
- Gas phase tellurium chemistry, effect of organics → NKS ORTEF project currently ongoing

Thank you for all partners, NKS, Nuclear Reseach Institute Rez!

Thank you for your attention!

CHALMERS