GEN IV International Forum SM

GEN-IV COOLANTS QUALITY CONTROL

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CEA, France

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Meet the Presenter

Dr. Christian Latgé graduated with a degree in Chemical Engineering (1979) and earned his PhD from the Institute National Polytechnique in Toulouse (France). His PhD in CEA Cadarache was dedicated to Na chemistry and purification systems. He participated in the start-up and then operation of Superphenix and operational feedback analysis (Phenix, Superphenix and foreign reactors), in the field of chemistry, radiochemistry and technology. He was also involved in design activities in EFR & SMFR. As Head of Service, he coordinated activities dedicated to process studies for decontamination and nuclear waste conditioning in Cadarache. He carried out studies dedicated to tritium systems and hydrogen risk mitigation for the ITER project. As director of the international project "Megapie," Dr. Latgé led a team dedicated to the development of a lead-bismuth eutectic spallation target for nuclear waste transmutation. He served as the Head of Sodium School in Cadarache and now teaches at CEA-INSTN and several French universities. He has been involved in several educational sessions organized by the IAEA on Fast Reactors and he is the CEA representative on the GEN-IV International Forum Education & Training Task Force. He is currently involved in SFR and recently in the ASTRID project as an expert, and he is involved in several international collaborations related to the development of Fast Neutron Reactors.

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Coolant Functions for the Primary Circuit of XFR

- The coolant(s) must accomplish the following key tasks
  - Extract heat from the core: high specific heat and thermal conductivity ensure good extraction
  - Transfer heat to an energy conversion system (steam generator or exchanger + turbine) or to a system which directly uses the heat: heavy oil extraction (oil shales), thermochemical production of hydrogen, desalination of sea water
  - Assure safety by providing the system with a degree of thermal inertia
- In a Fast Neutron Reactor, the coolant must NOT
  - Significantly slow neutrons
  - Activate under flux, producing compounds which create unacceptable dosimetry
  - Change the behavior of structural materials
  - Induce unacceptable safety conditions
  - Induce insurmountable operating problems
  - Lead to wastes which can’t be processed during operation or dismanting

Coolants Used in Nuclear Applications

Fission
Sodium for fast neutron reactors (many SFRs)
Sodium-Potassium (Na-K) for fast neutron reactors (DFR)
Lead for fast neutron reactors (FNR) cooled by lead (LFR)
Lead-bismuth eutectic for subcritical reactors (ADS: Accelerated Driven Systems), including their spallation targets and Russian submarine FNRs
Molten Salt for molten salt reactors (MSR)
Gas: He for Very High Temperature thermal Reactors (VHTR), for gas-cooled fast neutron reactors (GCR)
He-N_2 or Sc-CO_2 in innovative energy conversion systems (ECS) for SFRs
Water-steam as the primary coolant in pressurized water reactors (PWR), supercritical water in supercritical water-cooled fast reactors (SCWR), etc. and water-steam in the team generators of energy conversion systems (ECS) for sodium-cooled reactors, lead-cooled reactors, etc.
Fusion
Lead-lithium eutectic for blankets in thermonuclear fusion reactors
Lithium as a target neutron generator for the IFMIF project (International Fusion Materials Irradiation Facility) (Lithium investigated as a coolant for space applications, due to its very low density)
Note: In spallation targets, the lead-bismuth eutectic also serves to produce neutrons. In fusion, lithium acts as a generator of tritium.

Coolants: Sodium (Natrium)

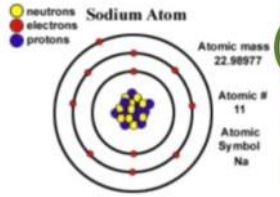
The so-called « natron » was already known from Aegyptians, as « **neter** », from ancient Aegyptian langage **nṯr(j)**, word which means that this product was extracted from dryed lake, located in the desert of « Nitrie » **(Wadi El Natrun)**.

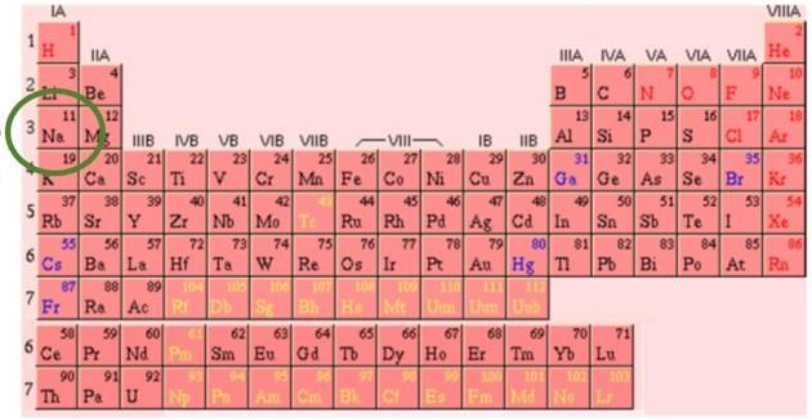
Na: Prepared in 1807 by Sir Humphrey Davy (Caustic soda electrolysis)

No specific toxicity (like lead) but irritation and local corrosivity
Biological utility: essential
Daily recommended consumption: 2 to 15g;
MNa in human body (70kg): 100g
- Bones: 10 000 ppm
- Blood: 1970 mg/l
Yearly output: c. 200 000 ton.year^{-1}

Na in the alkali metal family : Name coming from arabic : al kaja meaning : ashes coming from sea

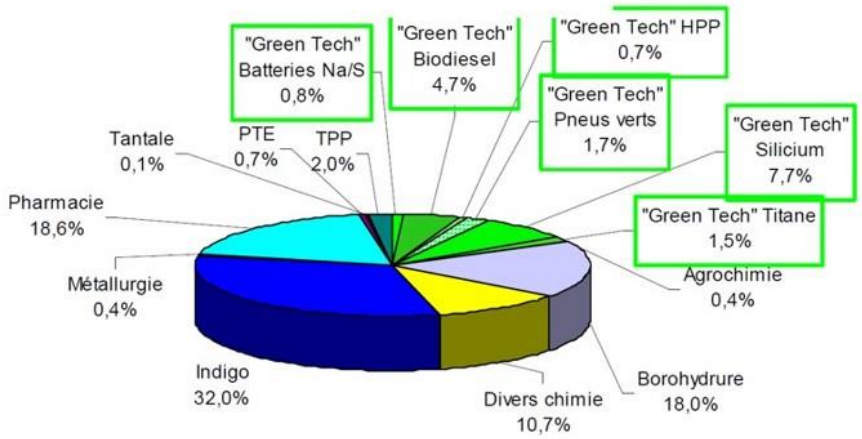
قَلَوِيّ





Wadi El Natrun

Indigo



Green Tech =17,2%

Some explanations:
-TPP triphenyl phosphine used for the synthesis of vitamin A
-HPP High Performance Pigment

Coolants: Lead

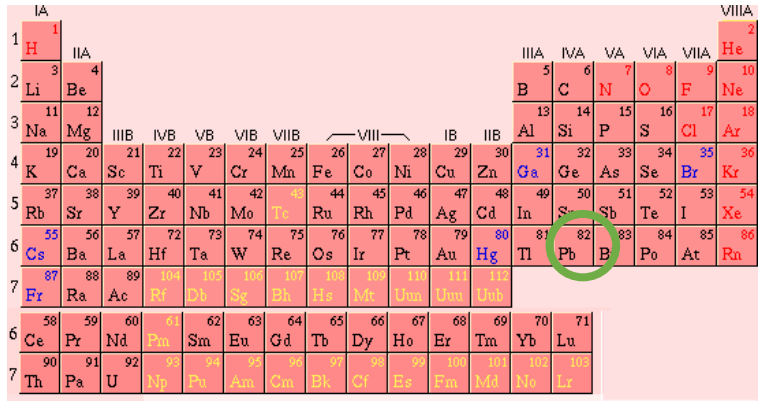
- Relatively low cost,
- Two main production routes:
  - primary production from mined lead ore
  - secondary production, where it is recovered from recycled products (mainly batteries)

Lead Properties
Symbol: Pb
Atomic Number: 82
Atomic Mass: 207.2 amu
Melting Point: 327.5°C (600.65 K)
Boiling Point: 1740.0°C (2013.15 K)
Number of Protons/Electrons: 82
Number of Neutrons: 125
Crystal Structure: Cubic
Density & 293 K 11.36 g/cm^3
Colour: bluish

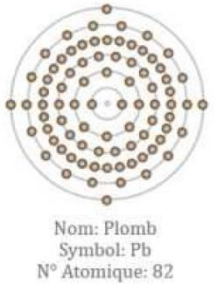
Courtesy of ILA

- Used because of its malleability and resistance to corrosion
- Figurine found in Egypt back to 4,000BC. Later, used by the Romans for water pipes, aqueducts, tank linings and cooking pots and then by ancient scientists in early cosmetics, paints and pigments….

Water ducts from roman city Arles (France)



at 500°C		
	sodium	lead
Melting point (°C)	98	327
Boiling point (°C)	882	1737
Density (kg/m3)	832	10390
Dynamic viscosity (Pa.s)	2.3 10-4	18.9 10-4
Specific heat (J/kg/K)	1262	149
Thermal conductivity (W/m.K)	67	15
capture cross section (barn)	2.8 10-3	4.7 10-3
Activation	22Na 2.6 ans 24Na 15h	207Pb 52h



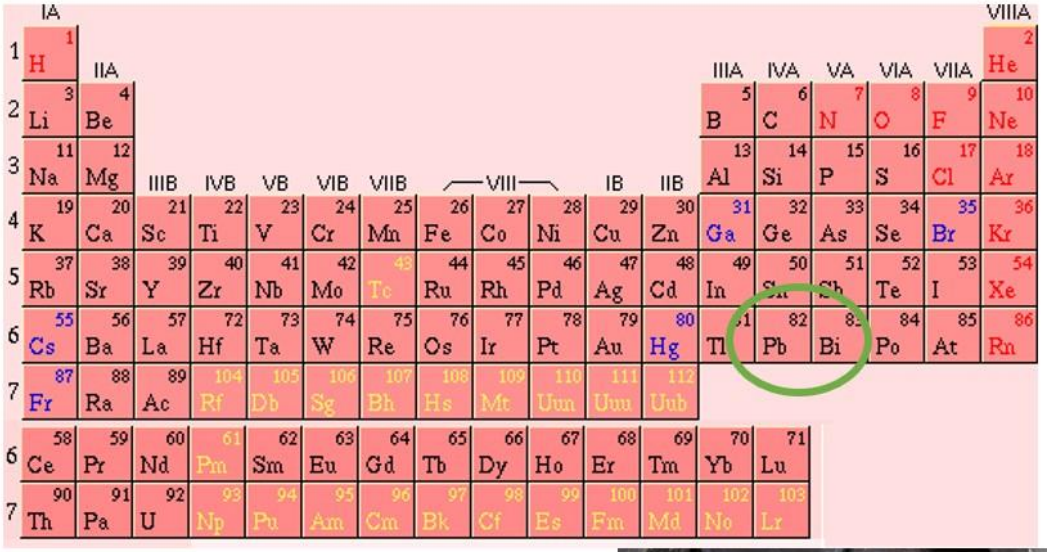
Coolant for FBRs alternative options: BREST-300, ALFRED, CLEAR

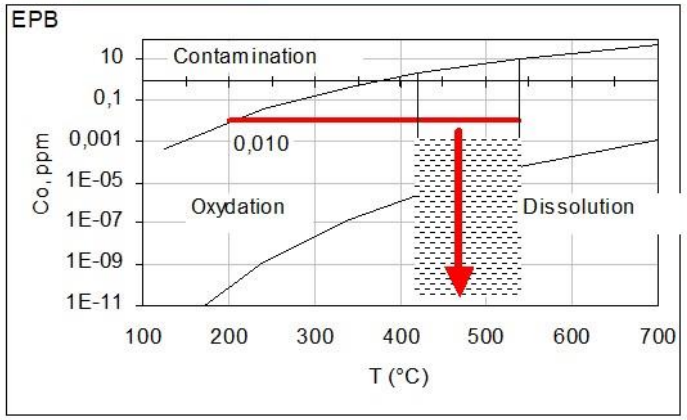
Coolants: Lead-Bismuth Eutectic

- Bismuth: By-product of Lead ore
- Low melting point (125°C), compared to lead
- Lead can be oxidized with significant precipitation of PbO particles
- No chemical reaction with water but water may violently vaporize depending on local conditions (ie ΔT between the 2 phases, dispersion…)
- Significant corrosion➔ protective coating required:
  - Al, Si…. coatings, or
  - [O] controlled to maintain a protective oxide film at the surface

  ➔introduction of steam+H2 and

  ➔Introduction of O by an "equilibration", method using PbO pellets)





- Very large operating feedback available on this coolant:
  - USSR submarines and dedicated research,
  - ADS studies (MYRRHA, CLEAR, MEGAPIE, EU projects…)
- Note: LBE has been investigated as an alternative coolant for intermediate circuits of SFR
  ➔ if LBE ingress in primary vessel, interaction with primary Na ($BiNa_3$ – ΔH=137 kJ/mol LBE)

Main Impurities

- Primary circuit
  - Initial impurities in « nuclear grade » coolant, prior to reactor operation, can induce deleterious effects: coolant (Li) and cover gas contamination (K), corrosion (Cl, F…), clogging (Ca in Na), mechanical effects (C), nuclear reactions (U, B..),….
  - Main impurities introduced during operation:
    - Oxygen and moisture from fresh metalic surfaces, during handling operations
    - Metallic oxides dissolved in coolant
    - Activated corrosion products (^{58}Ni, ^{60}Co, ^{54}Mn…) dissolved or particles
    - Fuel particles and Fission products (^{137}Cs…) (pin rupture)
    - Tritium from Pu ternary fissions, B_4C
- Intermediate circuits of SFR (Na) :
  - Na-water products (H_2, NaOH converted into O and H dissolved in Na)
  - H_2 produced by aqueous corrosion in SGU, migrating towards Intermediate circuit (driven by Richardson law)
- Energy Conversion System (Based on Brayton or Rankine thermodynamic cycle)
  - Tritium from primary circuit (and diffusing though SGU walls in the water (Energy Conversion System)
- All circuits: Potential oil ingress (pumps), metallic filling due to maintenance, etc…

Why is it necessary to control quality and to purify the coolant?

- Primary coolant of XFR:
  - [O] is a key parameter of corrosion
    - For SFR→ contamination→dosimetry → necessity to decontaminate (handling, repair, ISI,..): [O]<3ppm
    - For HLM-FR (or ADS)➔ necessity to master dosimetry and to eliminate corrosion particles (filtering)
  - [O] well mastered can help to maintain oxide layer stable (protection against hard corrosion in heavy liquid metals HLM). It also allows enhancement of tribology.
  - [O] can induce precipitation of coolant oxide : issue for HLM: PbO particles due to very low dissolution rate; in case of very large O ingress, it can modify the composition of binary alloys ie Pb-Bi... (it is not a problem for Na),
- For Intermediate circuits of SFR (Na) :
  - [H] has to be maintained as low as achievable in order to detect as soon as possible a water ingress in Na (Na-H_2O reaction generates H_2): [H] <0.1 ppm
  - In steady-state operation, aqueous corrosion in SGU produces Fe_3O_4 and H: H diffuses towards intermediate Na.
  - Moreover, Na purification allows to minimize tritium release. (Nota: Tritium release is a common issue for all nuclear systems, including HLM cooled FRs
- For all the circuits :
  - Control plugging hazards in narrow gaps, tubing, openings, seizing of the rotating parts, reduction of heat transfer coefficient in IHX (Intermediate Heat Exchanger)…

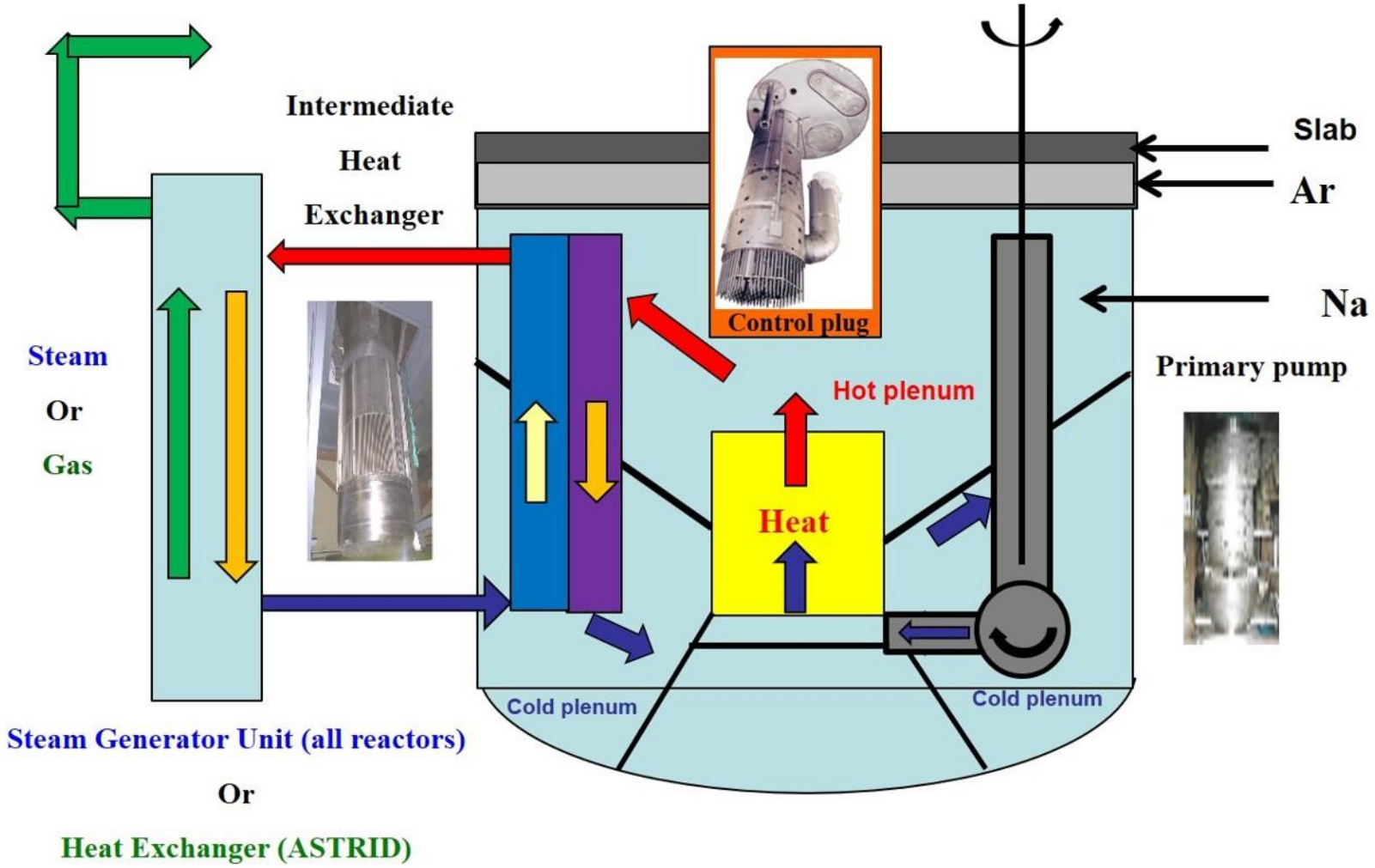
➔ to limit the plugging hazard, necessity to maintain [O] < [O]* and [H] < [H]* at the coldest point of the circuits, for all operating conditions ; value recommended in SFRs: Tsat < Tcp - 30°C

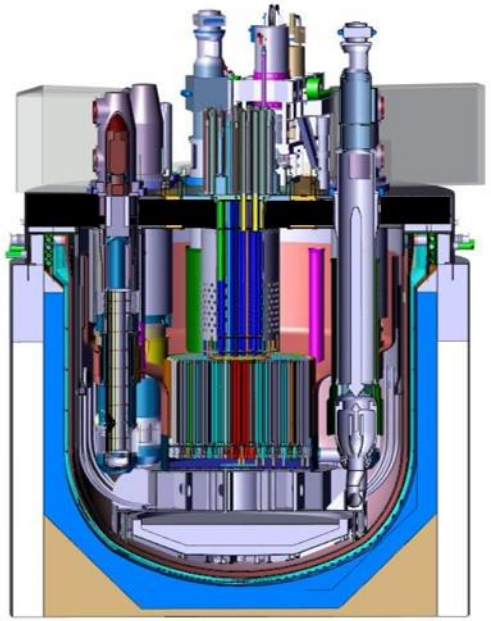
Various Processes to Purify LM

- **Cold trap** (O & H: impuritie's crystallization)
- **Hot trap** (O or H: gettering effect)
- **"RVC Trap** (Cs: adsorption on carbon solid foam, followed by absorption)
- **Mechanical Filter** (sintered filter, mesh… for particles)
- **Skimmer** (for floating oxide layer)
- **Chemical reduction** of metallic oxides,
- ….

Sodium

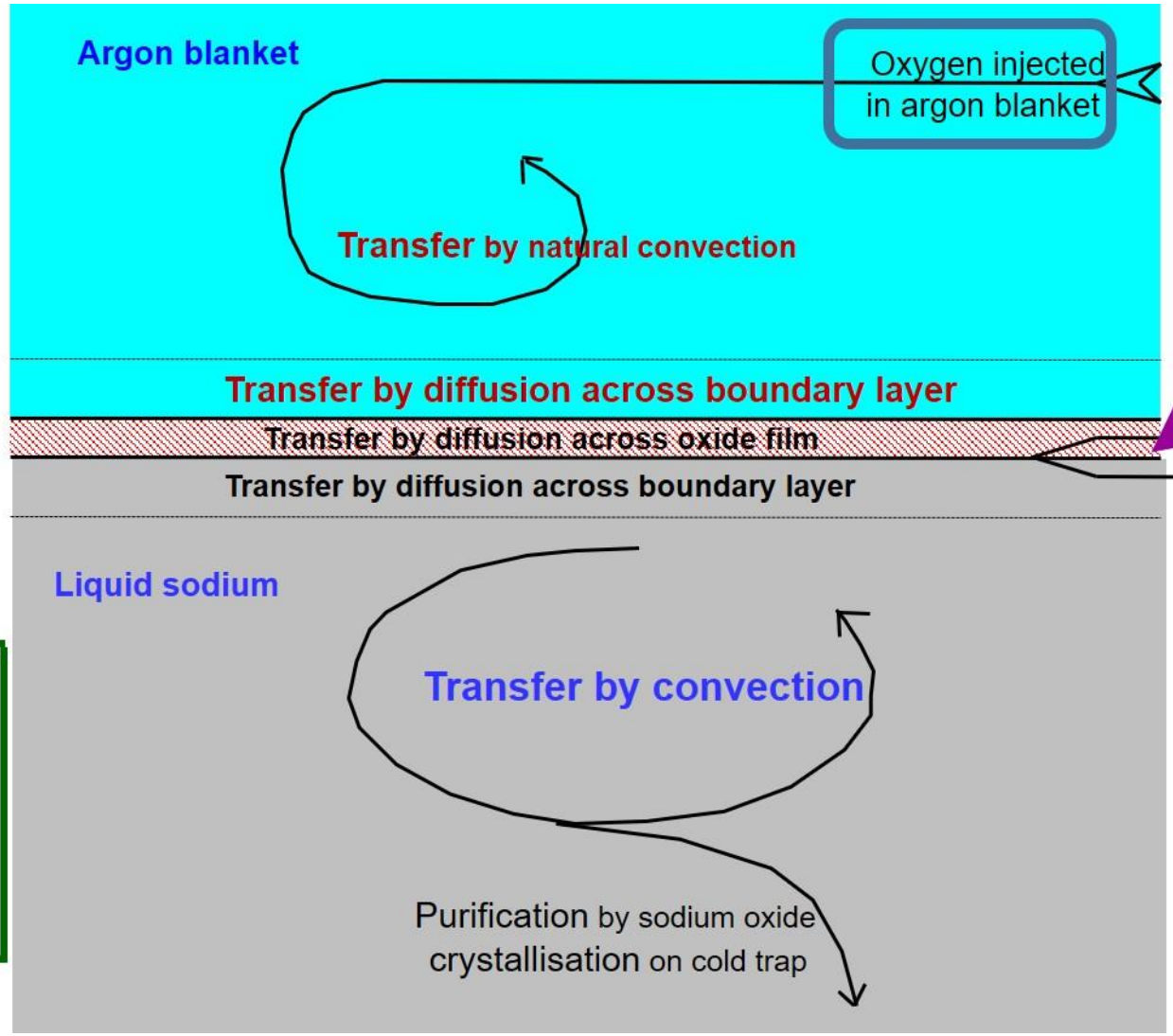
SFR (Pool Concept)





ASTRID

O Transfer in Primary Sodium



P_O low:

No combustion

- At low T: Na_2O forms
➔ "mirror" effect lost
- At high T: ↗ $[O]_{Na}$

Chemical reaction at film/Na interface

Oxide film dissolution

O & H Solubilities in Liquid Na

Wittingham solubility law

$$\log_{10}[H(ppm)] = 6.467 - \frac{3023}{T(K)}$$

Noden solubility law

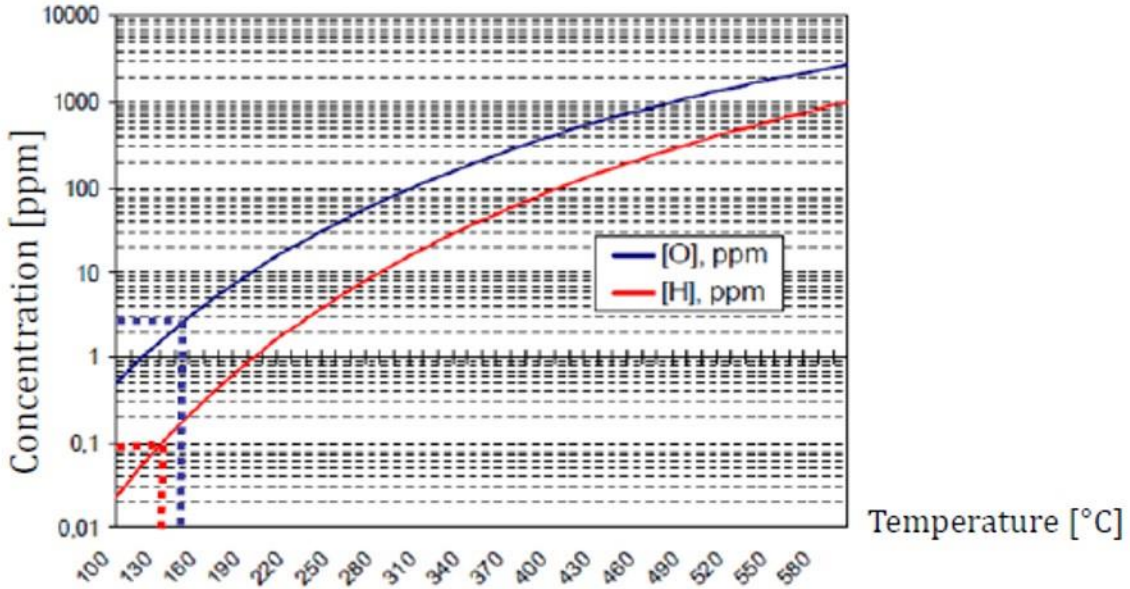
$$\log_{10}[O(ppm)] = 6.250 - \frac{2444.5}{T(K)}$$

Na can be purified by cooling, leading to crystallization of O and H as Na_2O and NaH in a "cold trap"

Solubilities almost nil around the melting Sodium T_{fusion}=97.8°c

Primary loop : $[O^{2-}]$<3ppm → $Na_2O_{(s)}$

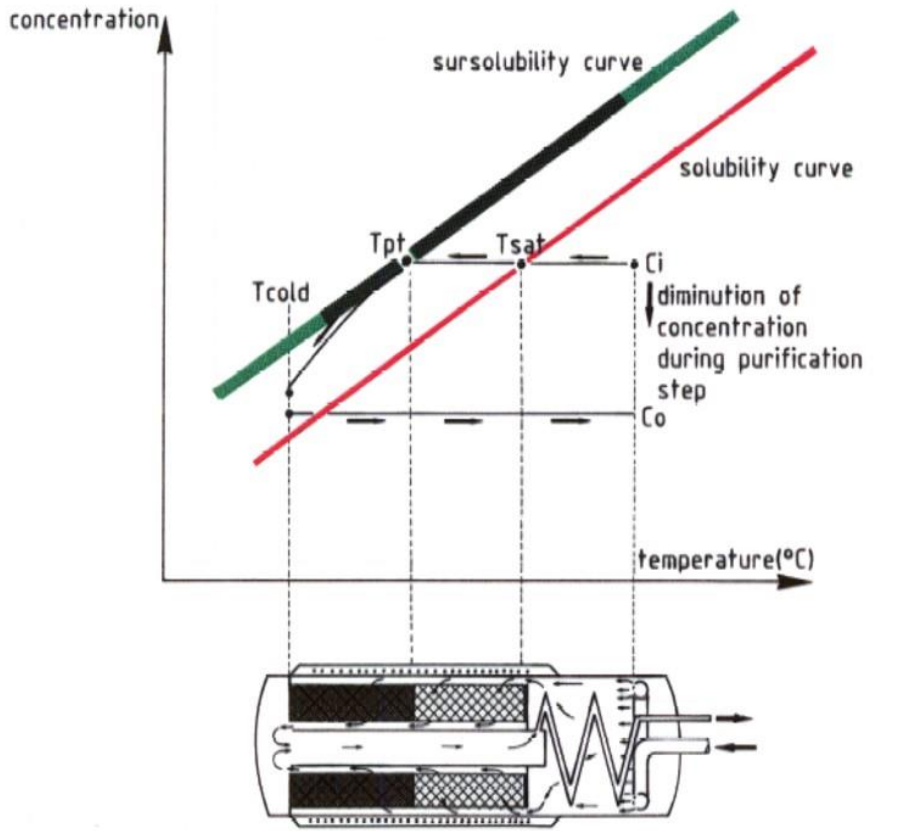
Secondary loop : $[H^-]$<0.1ppm → $NaH_{(s)}$



➔ O control: no necessity to keep a minimum value to protect structures (coating) No risk of Na_2O precipitation in Na bulk)

➔ Ternary oxydes ($Na_xM_yO_z$ limited amount, thermodynamic stability depends on T, [O])

Cold Trap Principle



C. Latgé
« Sodium quality control; French developments from Rapsodie to EFR".
Conférence FR09 Kyoto Décembre 2009

Crystallization kinetics, given for one impurity O or H,]:
in [kgNa_2O/s] or [kgNaH/s]

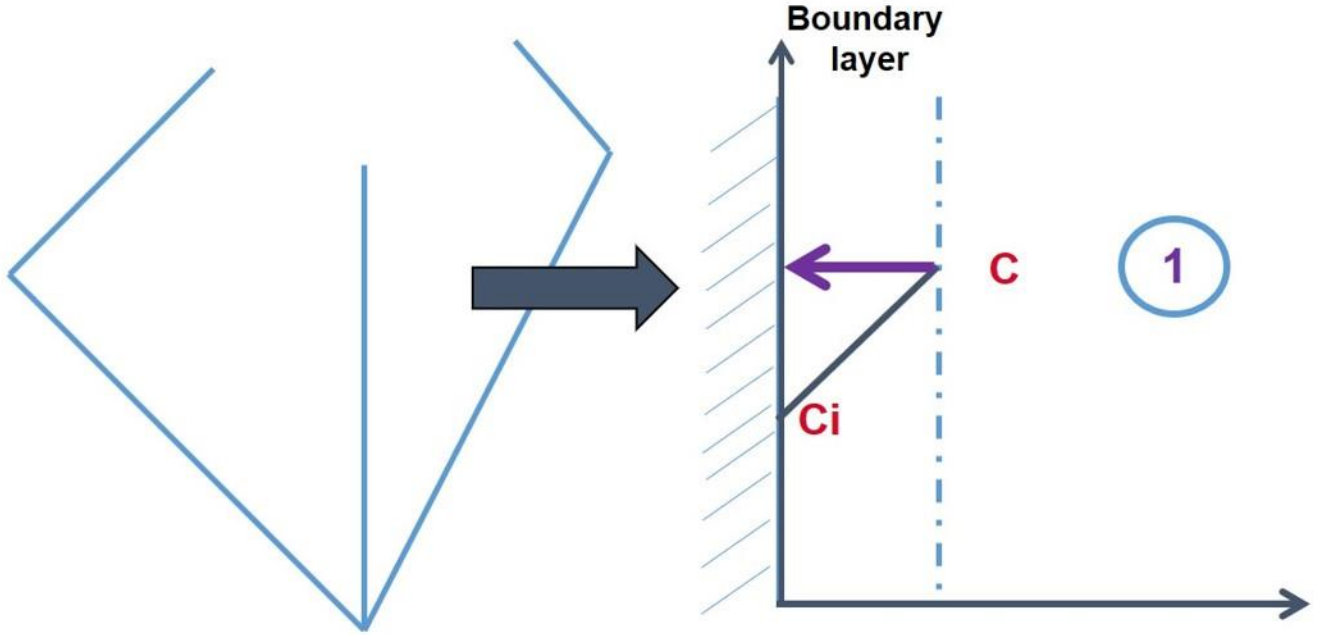
$$r_{jX}(T,t) = k_{oX}\exp(-\frac{E_X}{RT})\,A_{jX}(t)\left[\frac{(C-C^*)}{1.10^{-6}\,\rho_{Na}}\right]^{n_X} = Ko_X\,A_{jX}(t)[\Delta C]^{n_X}$$

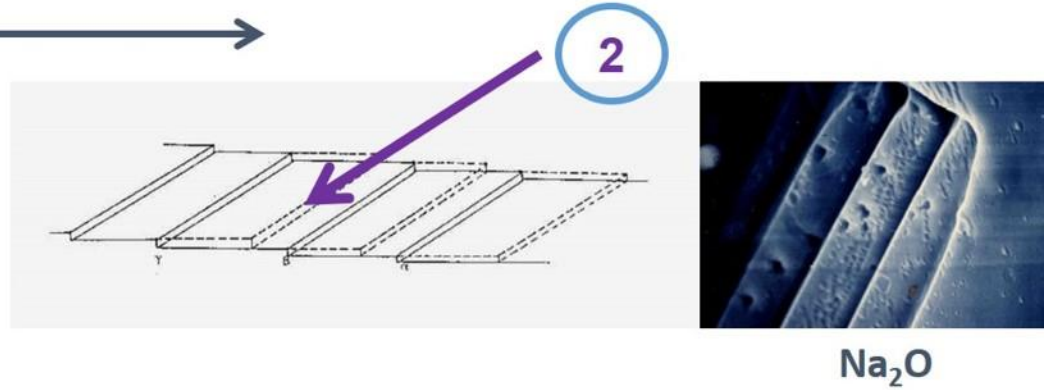
In this equation:

Index X refers to Nucleation (N) or growth (G)
Index j refers to the location on wire mesh packing (p) or cold walls (w).
k0 is the rate constant (kg/(s.ppmnx.m²)),
E is the activation energy (J/mol),
R is the Boltzmann constant (J/(mol.K)).
A is the crystallization surface of reference (m²)
(wire or walls for nucleation, nuclei and crystals for growth).
nX is the order of the crystallization process.
C*(kg/m^3) is the saturation concentration (from solubility law.)
ρNa is the sodium density in (kg/m^3)
(C-C*) is the supersaturation at temperature T(K).

Phenomena	Nucleation (N)		Growth (G)	
Impurity	Na_2O	NaH	Na_2O	NaH
E (kg/mol)	-60	-450	-45	-43.6
n	5	10	1	2

Crystal Growth





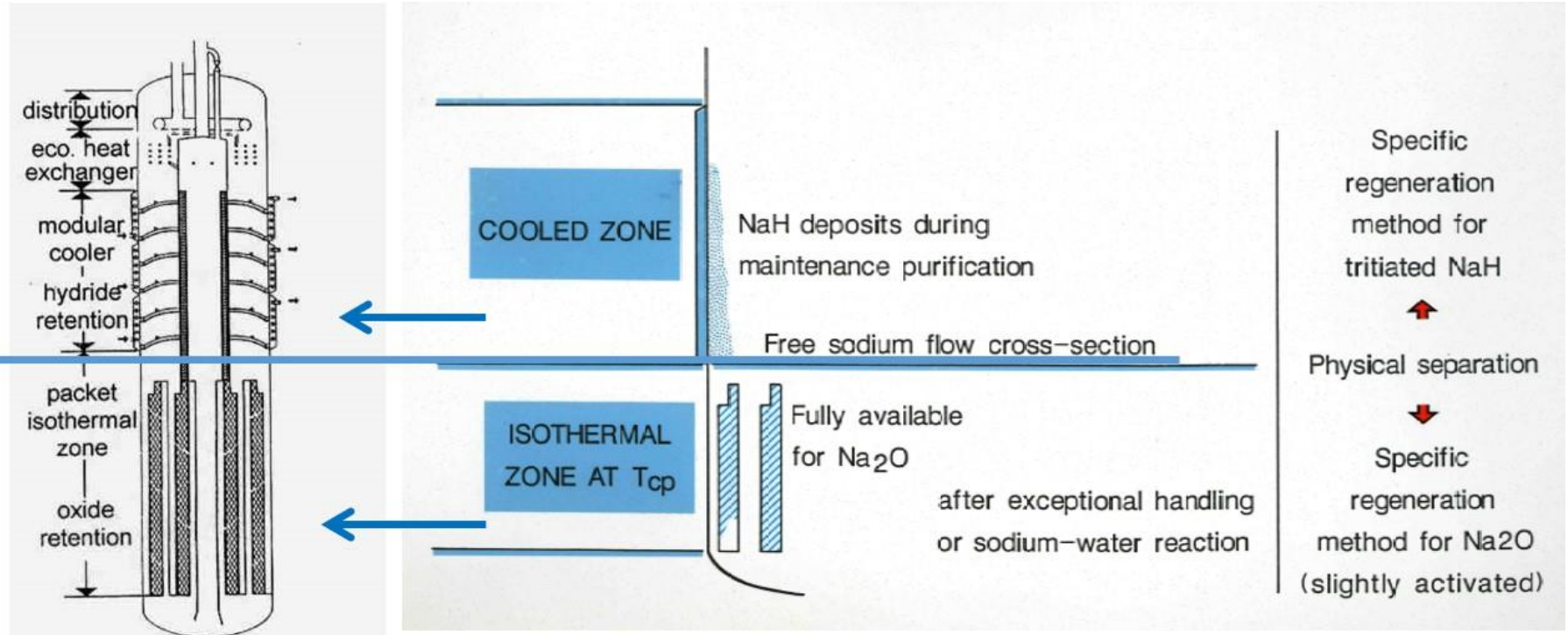
Na_2O

Step 1: Diffusion through the boundary layer

Step 2: Integration in the crystal lattice

➔ Kinetics of the overall phenomena = kinetics of the slowest step

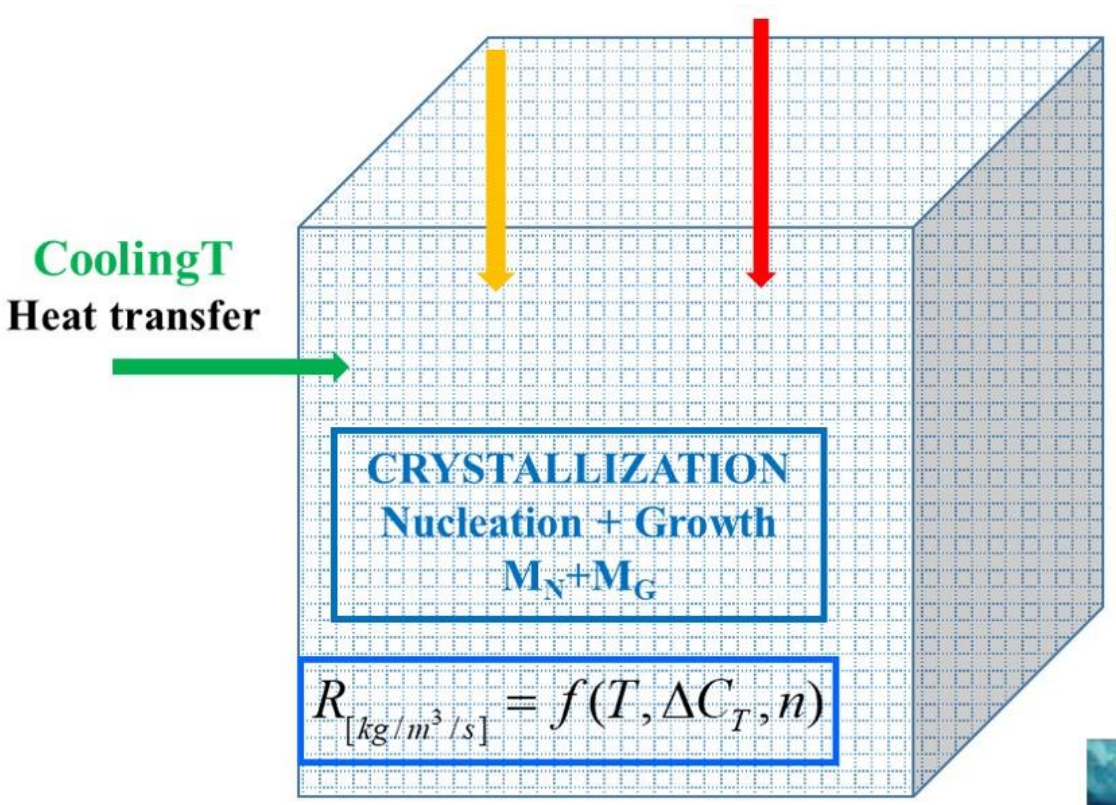
Experiments Carried Out on Na_2O and NaH

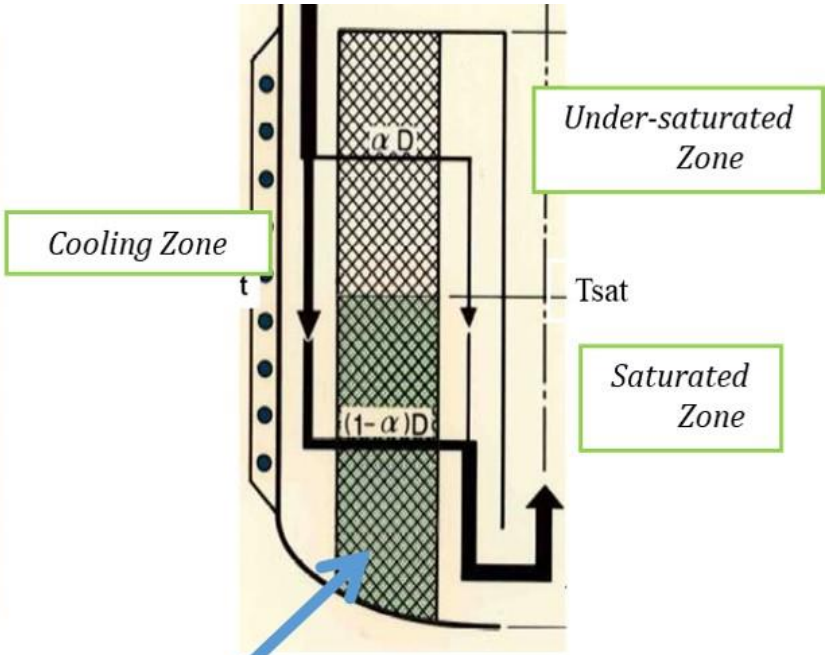


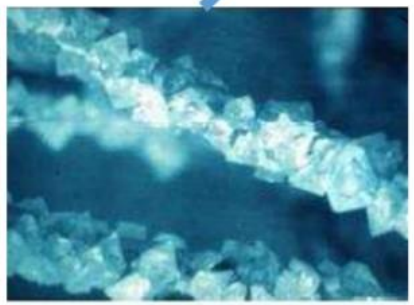
- For a cold trap designed with an upper packless cold zone:
  - ➔Na_2O crystallization only on wire mesh packing
  - ➔NaH crystallization essentially on cold walls of the system, (if thermal flux is enough)
- However, in case of a non-optimized packless cold zone, hydride might as well crystallize on wire mesh packing. Thus, co-crystallization occurs between sodium hydride and sodium oxide.

Hypothesis: kinetics parameters for NaH crystallization on cold walls identical to those on wire mesh packing.

Crystal Growth







Simulation Tool

Two types of crystallization behavior:

➔ Two different modeling approaches (cold walls or mesh).

➔ For both approaches:

System : a porous media with a porosity ϕ referring to the void fraction of the liquid phase.

Porosity is initially:

- equal to 1 with deposit on walls (NaH),

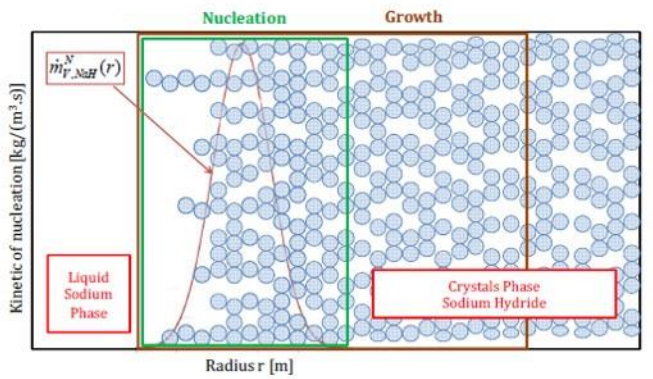
- equal to the void fraction of the mesh packing if the deposit occurs on wire mesh (Na_2O).

Mixture of crystal and liquid sodium in which void fraction changes with time and space, as well as its physical parameters such as permeability, diffusion or thermal conductivity…

Fluid assumed to be incompressible and each infinitesimal volume assumed isothermal.

➔The model takes into account hydrodynamics in porous media, heat transfer, mass transfer, and nucleation and growth kinetics

Numerical model solved by finite element method in Comsol Multiphysics® software. (Validated / experiments)



Interface tracking model for NaH crystallization on cold walls

Localization Deposit : Phase Field Equation

$$\frac{\partial e}{\partial t} + (\vec{v}_{SF}.\nabla)e = a\nabla^2 e + be(1-e)\frac{\nabla e}{|\nabla e|}$$

Front velocity

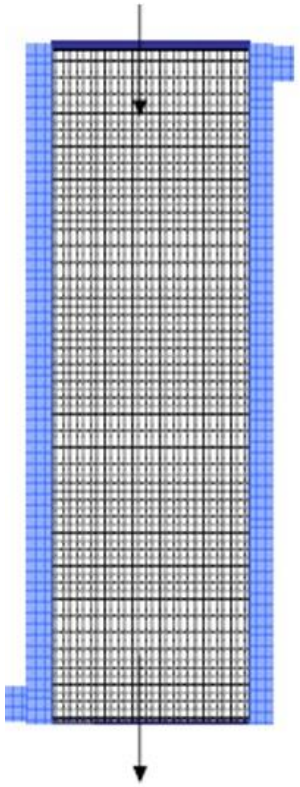
$$v_{SF} = f(R_N + R_G)$$

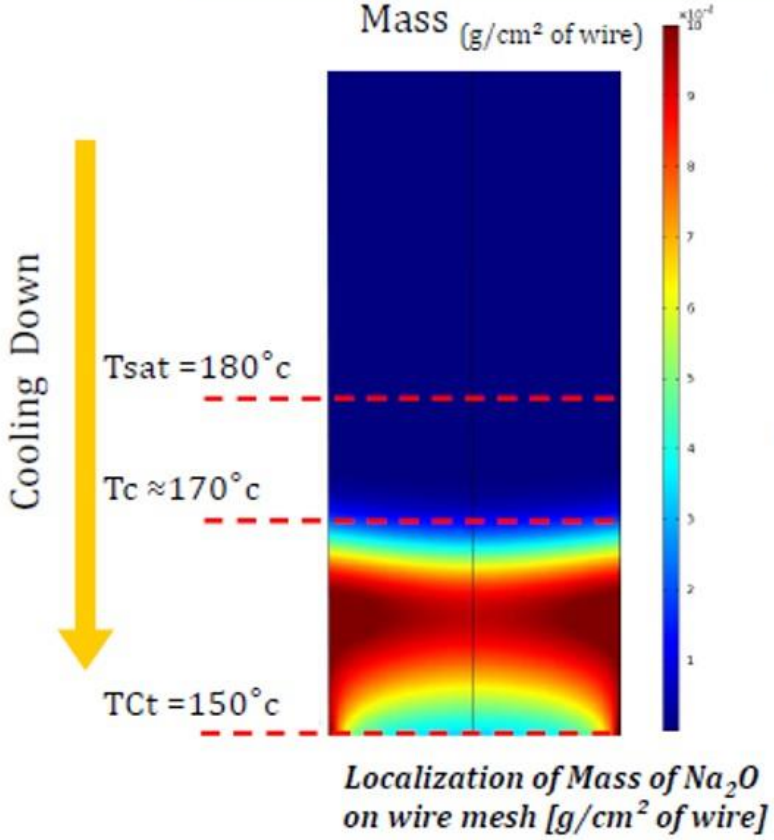
Na_2O crystallization modelling (in mesh): see next slide

Ref: N. Khatcheressian, C. Latgé, X. Joulia, T. Gilardi, X. Meyer, "Development of a coupled transfer model for Sodium purification system in a Fast Breeder Reactor," IAEA International Conference on Fast Reactors and Related Fuel Cycles – FR13 Paris (France) Mars 2013

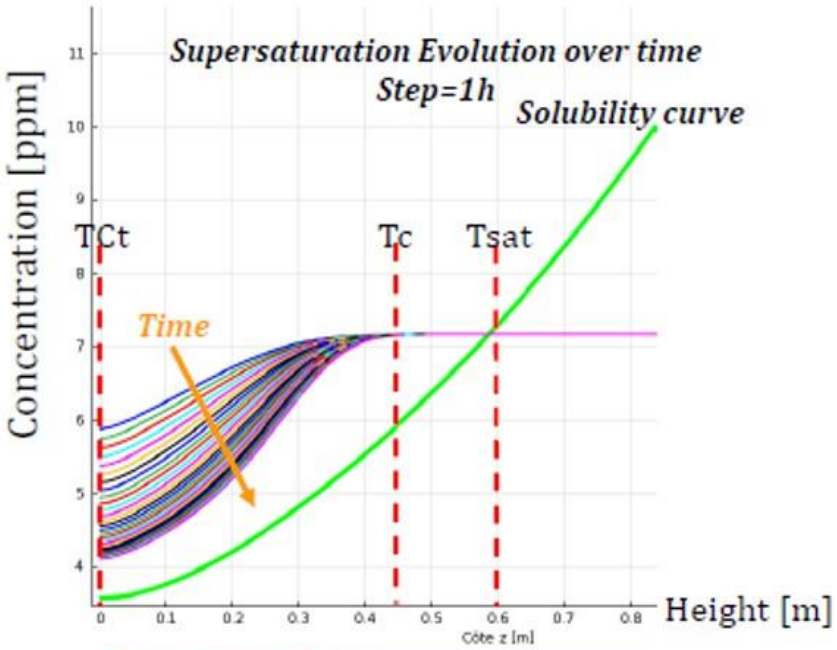
Na_2O Crystallization Modeling

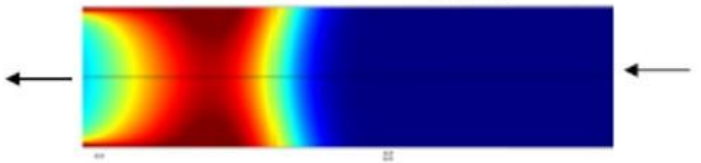
Oxide Trapping on packing: *Supersaturation Evolution*
Inlet Concentration **[O]=7,2µg/gNa**





Localization of Mass of Na_2O on wire mesh [g/cm² of wire]





Purification System: Design Methodology

- Identification of the impurities to be removed from the Na: mainly oxygen and moisture, potentially NaOH in case of very large sodium-water reaction.
- Assessment of their sources and their production rate (continuous & discontinuous) i.e. Na-H2O reaction considered as instantaneous: necessity to define a Na leak scenario and a probability of occurrence. Then, it is possible to estimate the amount of water reacted and consequently the amount of products to be trapped.
- Assessment of their potential sinks i.e. corrosion of structural material, deposition in the coldest points of the circuits.
  ➔ **induces specifications on the removal rate** to be obtained in order to prevent any deleterious effects, (exceptional corrosion due to large air ingress, stress corrosion cracking due to residual aqueous soda in remote locations…).
- Evaluation of the amount of impurities to be removed from the Na circuits, vessels, during the cold trap(s) operation over a given period depending on the strategy selected for the purification systems
  ➔ **induces specifications on the loading capacity**
- Selection of several trapping zones (cold trap: generally a combination of 2 zones):
  Zone 1: Cooling zone, equipped with or without stainless steel mesh, cooling zone, designed to trap (or not) NaH,
  Zone 2: Isothermal zone, located downstream from the cooling zone, after reaching the coldest point of the cold trap, equipped with stainless steel mesh

Many concepts developed in various countries

Performance Criteria for Cold Traps

Instantaneous efficiency: $E = (Ci-Co)/(Ci-C^*)$ $0<E<1$

Ci: concentration at the cold trap inlet
Co: concentration at the cold trap outlet
C*: concentration at equilibrium (solubility)

Purification rate: $Vp = E.(Ci-C^*).FNa$

FNa: Na flow-rate

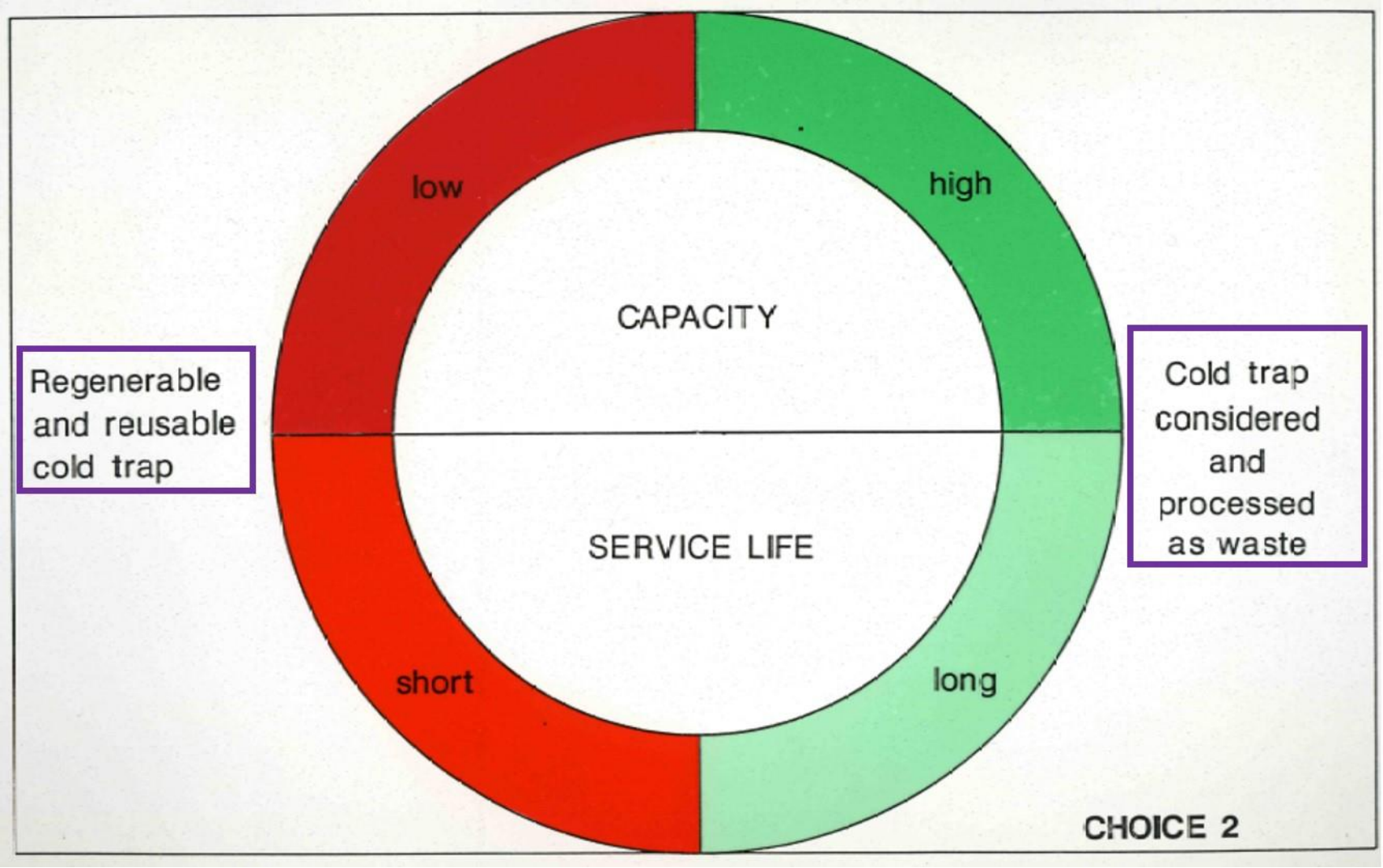
Capacity: $Cap = \Sigma \tau r.Ed$ (in unit of volume)

where τr = filling rate
and Ed = deposited element concerned (area, volume)

Compactness: $Comp = V1/V2$

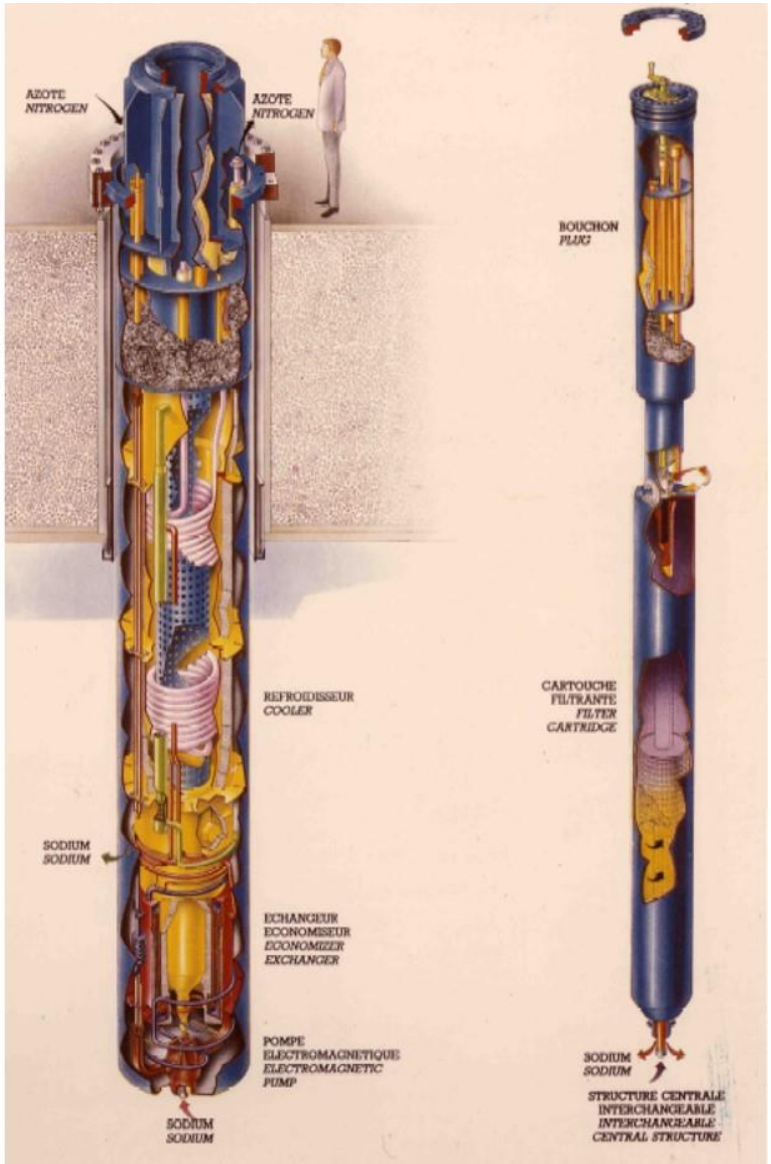
V1 = Maximum volume of the impurities retained in the trap
V2 = Internal volume of the trap in which the deposit zones are located

Basic Choices for Cold Trap



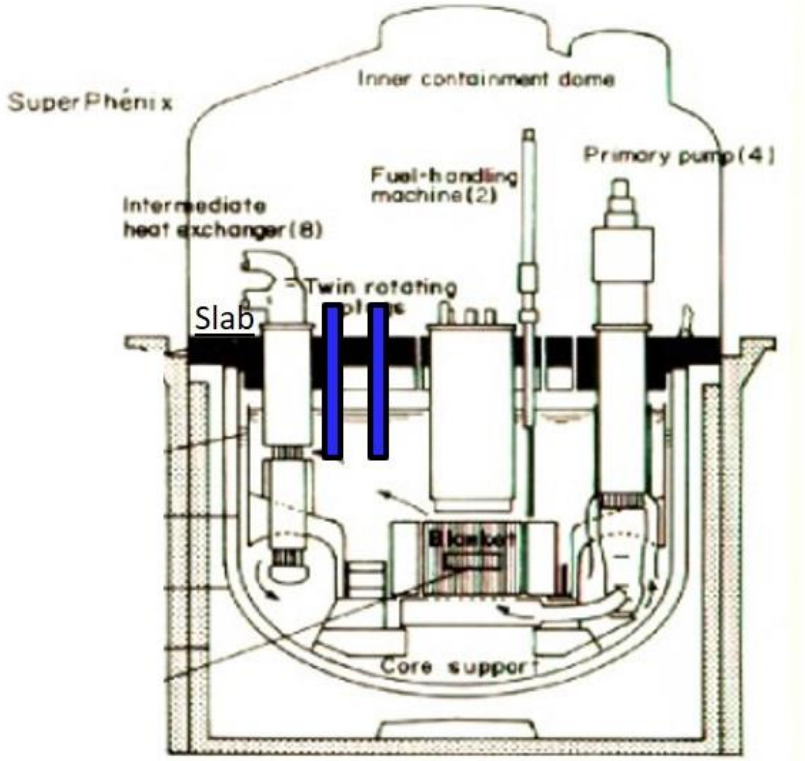
Alternative option:
Cold trap equipped with a cartridge (ie Primary integrated purification system)
(SPX, of interest for BN1200, FBR1&2)

Primary Integrated Purification Units of SPX (IPU)

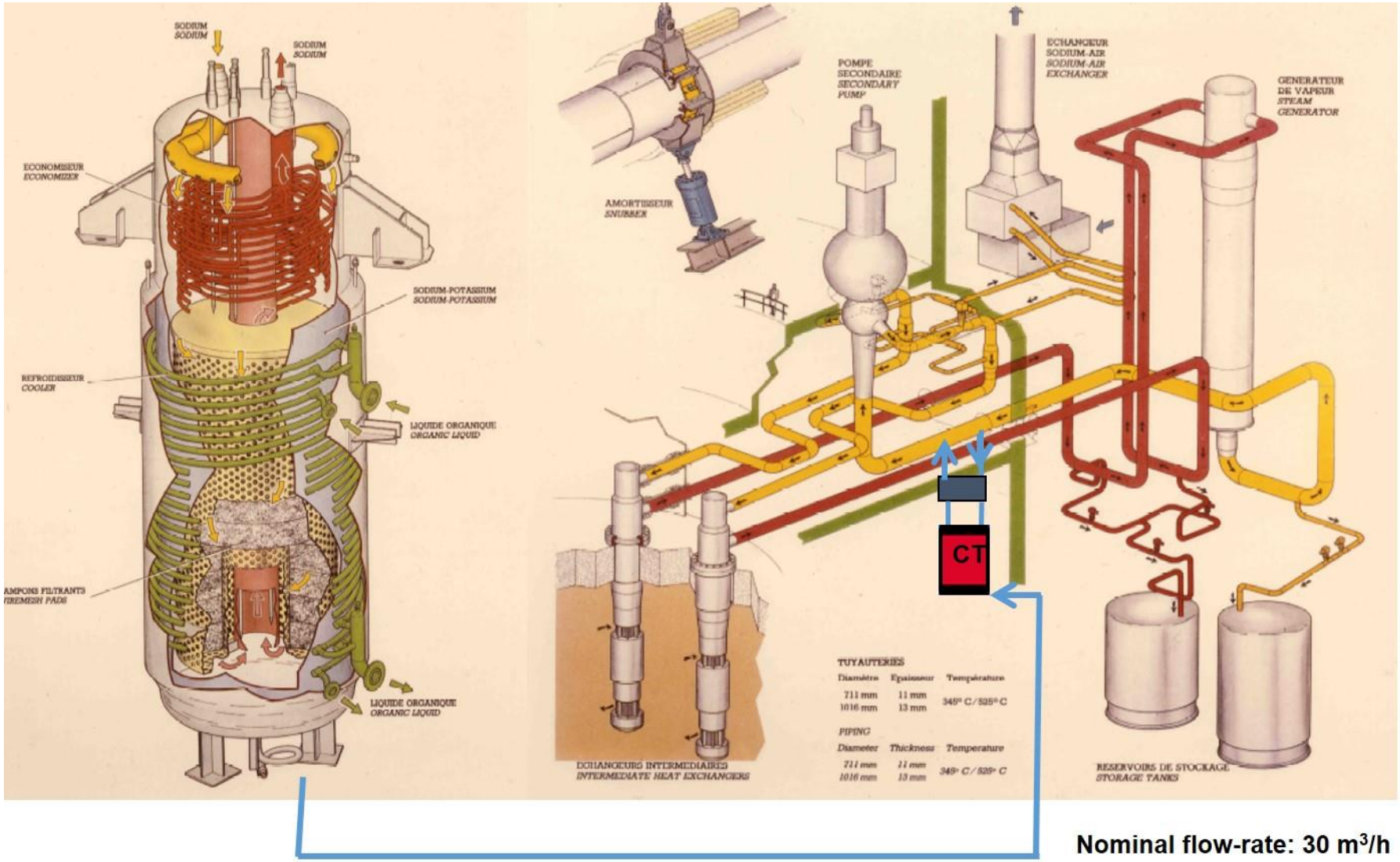


Nominal flow-rate: 10 m^3/h (each IPU)

Superphenix

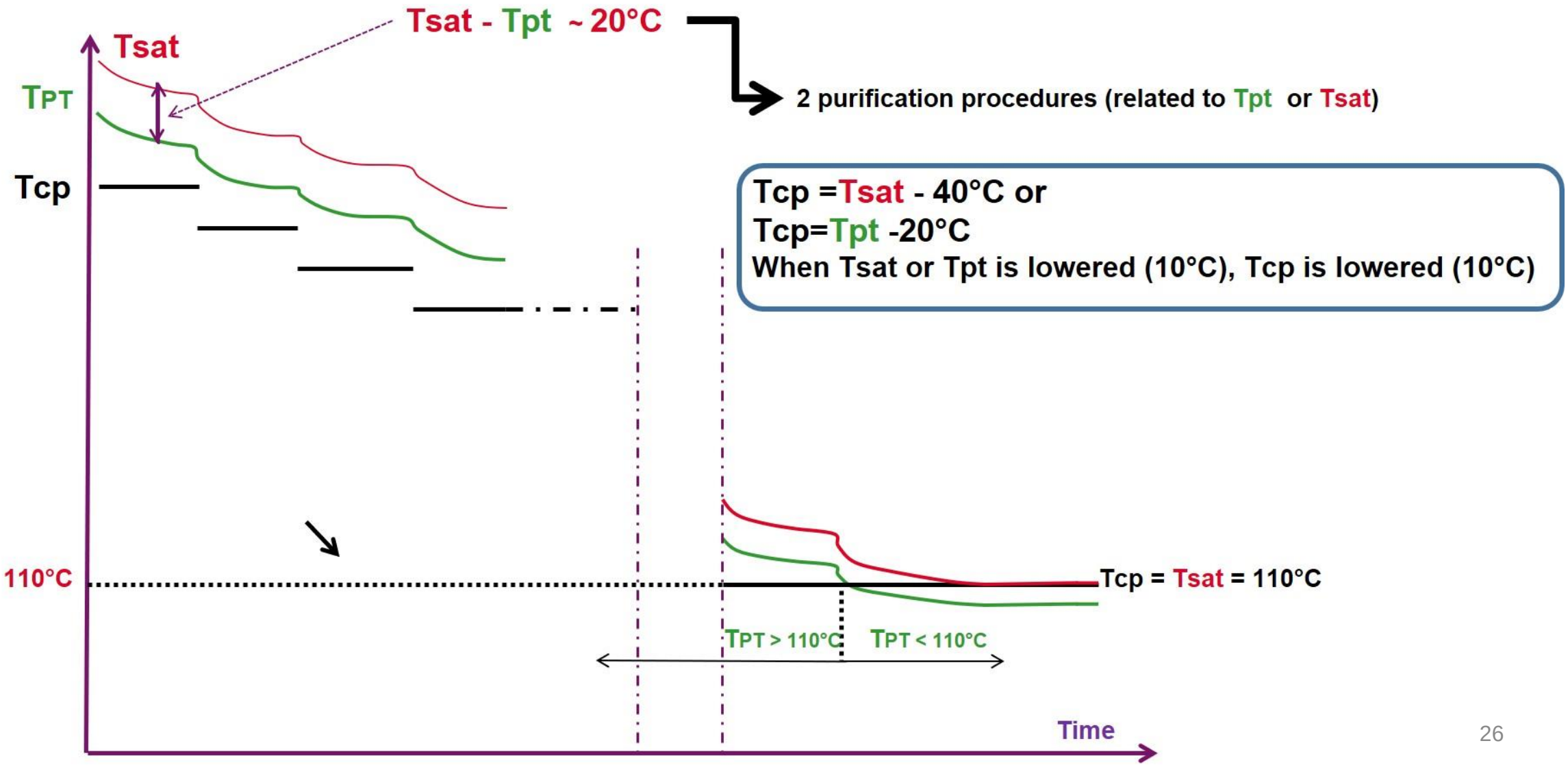


SPX Secondary Purification System (Loop Concept)

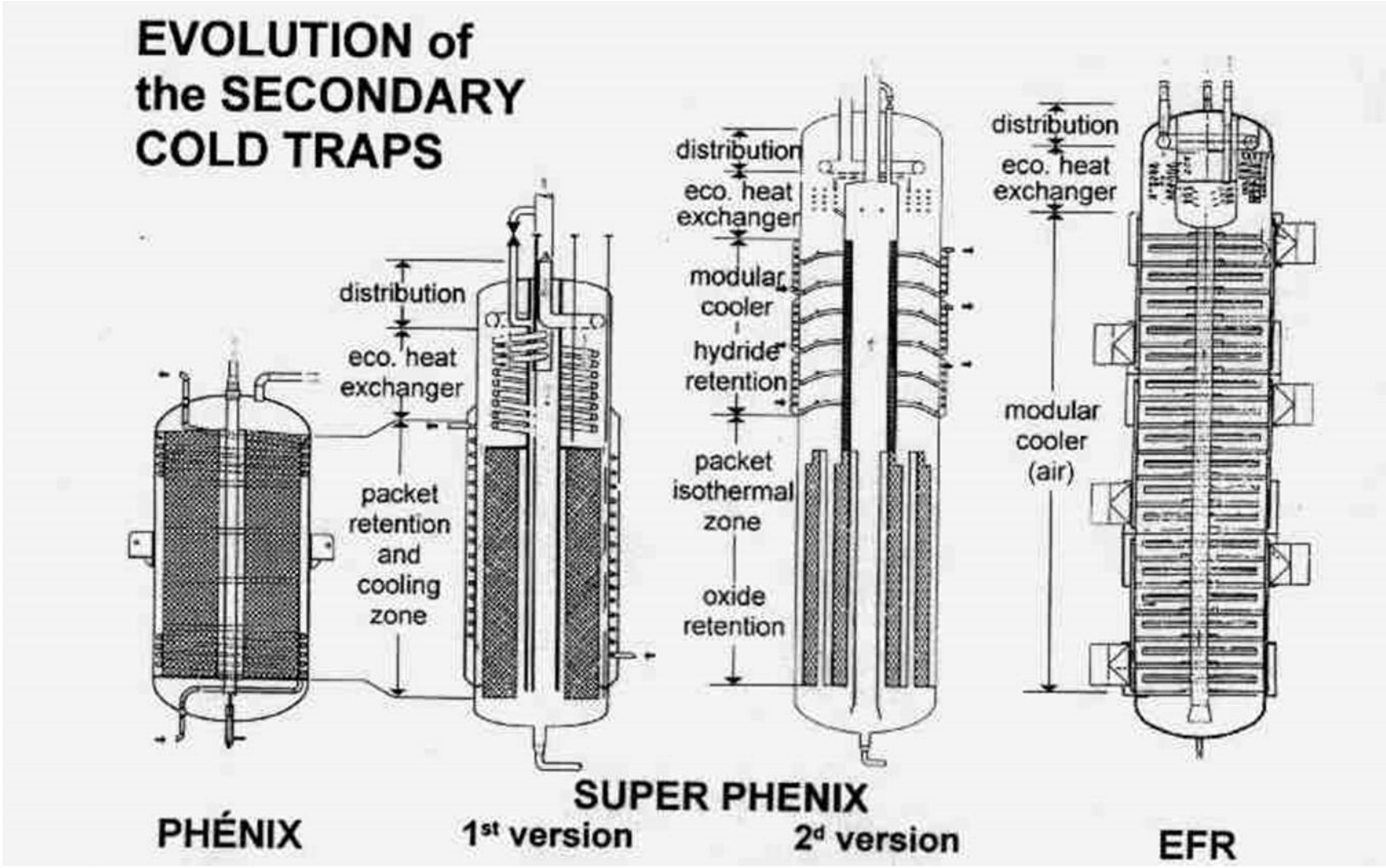


Nominal flow-rate: 30 m³/h

Purification Rule



Some Developments in CEA



Recently

Cheops facility

Astrid Reactor

Qualification Strategy for SFR Cold Traps

- **In the eighties:**

- Definition of the main requirements: pollution sources, purification rate, capacity, compactness)

- Design of the scale-one cold trap for the reactor, i.e. type of cold trap, cooling fluid, maximum allowable temperature, trapping zones to be implemented, …

- Identification of similitude rules (heat transfer, residence time in each zone, mesh density, loading capacity…) **and down-scaling of the mockup**

- Manufacturing of the mockup and implementation of dedicated chemical instrumentation (O-meter, H-meter) on the facility used for qualification tests

- Loading of the ancillary cold trap, used as a polluting device, with Na2O or NaH or both

- Operating the cold trap in various conditions in order to assess the allocated performances (efficiency, purification rate and capacity) and to confirm the operating rules.

- **Today:**

- Use of the new CEA code described here, validated using the previous experimental results, allows for a quite efficient design procedure, based on sequential calculations, avoiding long and very expensive experimental tests.

Chemical Instrumentation

Na continuous monitoring:

- **Plugging meter**: allow to estimate [O] and/or [H]

- **O-meter,** electrochemical device with reference electrode, …

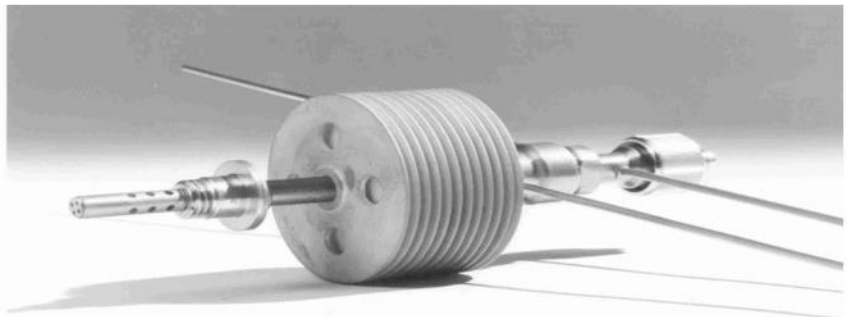
- **H-meter,** (diffusion +MS or electrochemical H-Meter)

- **C-meter,** electrochemical device with reference electrode, …

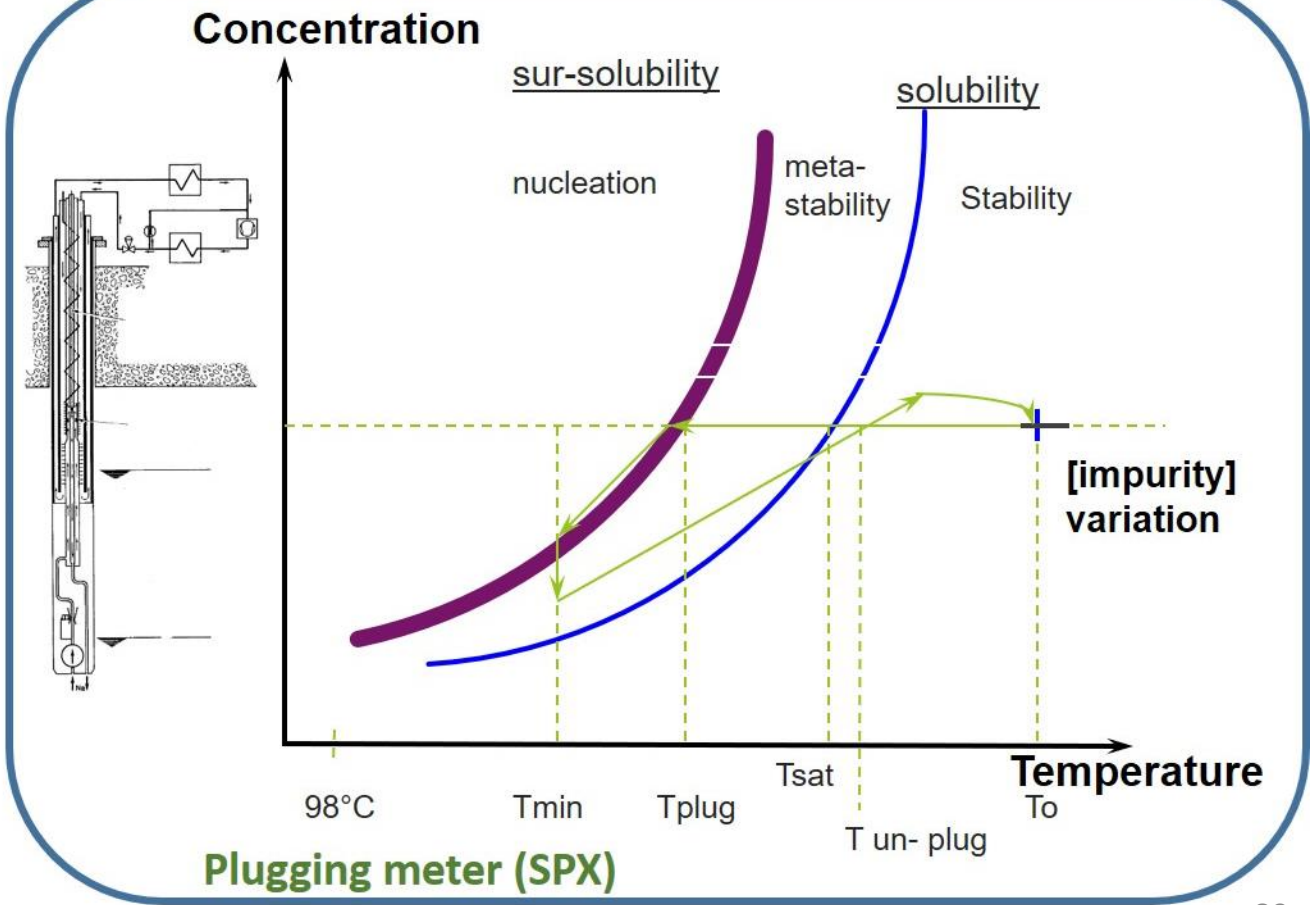
Periodical measurement: sampling (ie crucible) + analysis in Laboratory for radioactive species (activated corrosion products, tritium…)

Sampling crucible

Electrochemical cell (Courtesy UKAEA):
Thoria doped with Yttria,
Reference electrode : air, In/In_2O_3



Two O-meters currently being developed in CEA (DTN-Cad & DPC Saclay)



Plugging meter (SPX)

$Na\text{-}CO_2$ Interaction and Consequences

- Low temperature, < 500° C

Na/CO_2 reaction

Complex intermediates:

$Na_2C_2O_4$, Na_2CO_3, Na_2O, C, etc.

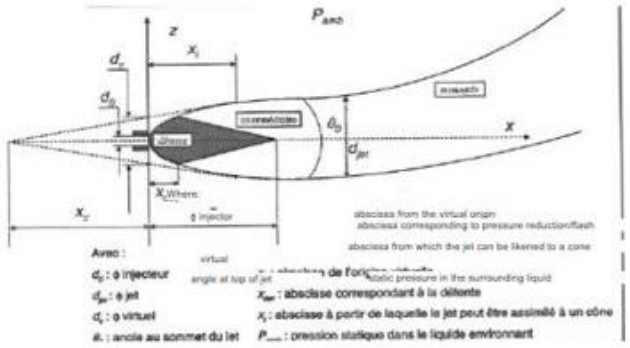
CO formation

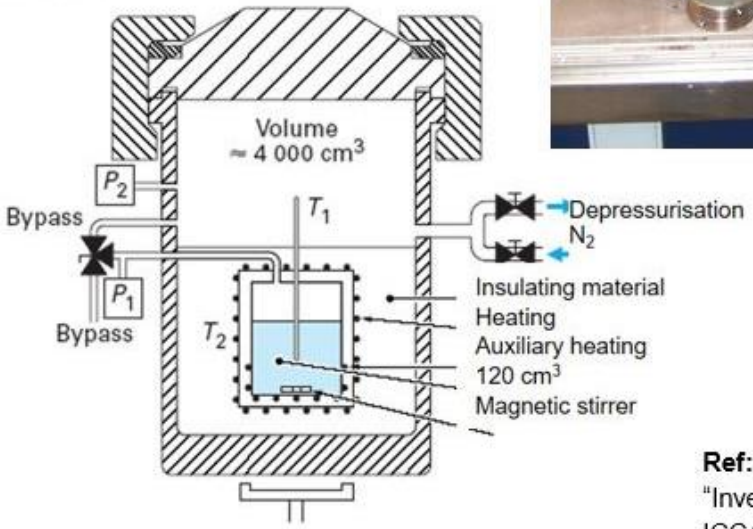
Na-CO reaction: induction period

- High temperature, 500-600° C

Na/CO_2 reaction is more rapid and global

$Na + CO_2 \rightarrow Na_2CO_3 + C$





Na_2CO_3 :
- **particles;**
- **Very low dissolution rates**

➔ **Filtration**

Ref: N. Simon, C. Latgé, L. Gicquel
"Investigation of sodium-carbon dioxide interactions with calorimetric studies"
ICCAP 2007 May 13th -18th Nice (France)

Sodium Decontamination – Cesium Trapping

Reticulated vitreous carbonaceous (RVC) traps : Cs adsorption on RVC

Efficient process ; operation at T around 200°C

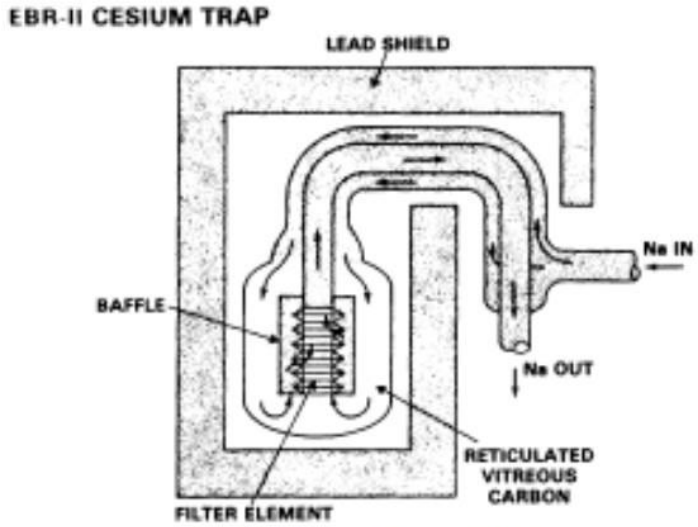
(possibility to reduce contamination by a factor 10 for each transfer through the trap)

Applied to EBR2, BOR60, RAPSODIE, CABRI…(and in future PHENIX)

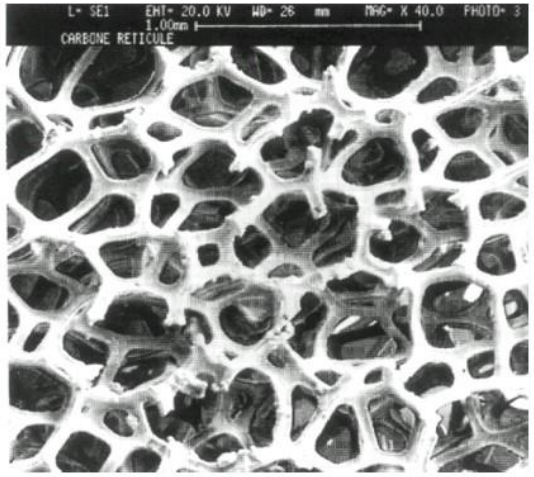
Note : necessity to take into account delay before Na treatment and decay ^{137}Cs/ ^{22}Na (Feedback from RAPSODIE)

3 cartridges adsorbed about 0.49 TBq ^{137}Cs

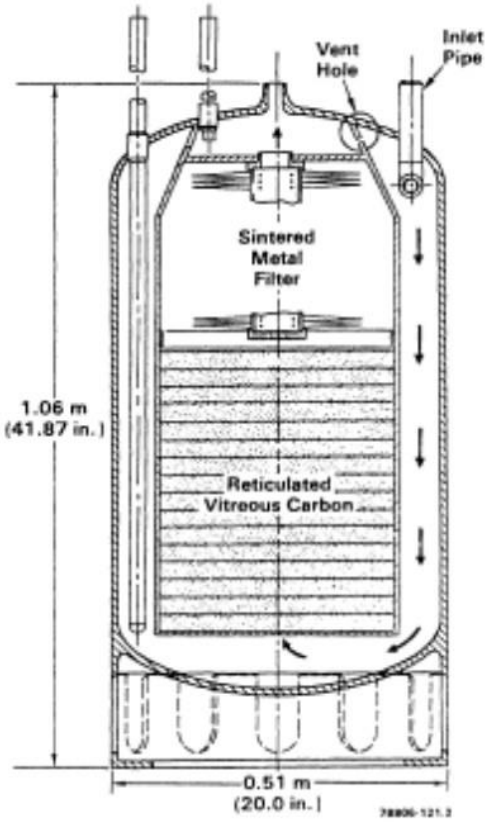
Will be applied soon for primary sodium of PHENIX, prior its treatment (conversion into NaOH)



EBR2 : piège RVC



RVC



FFTF : piège RVC

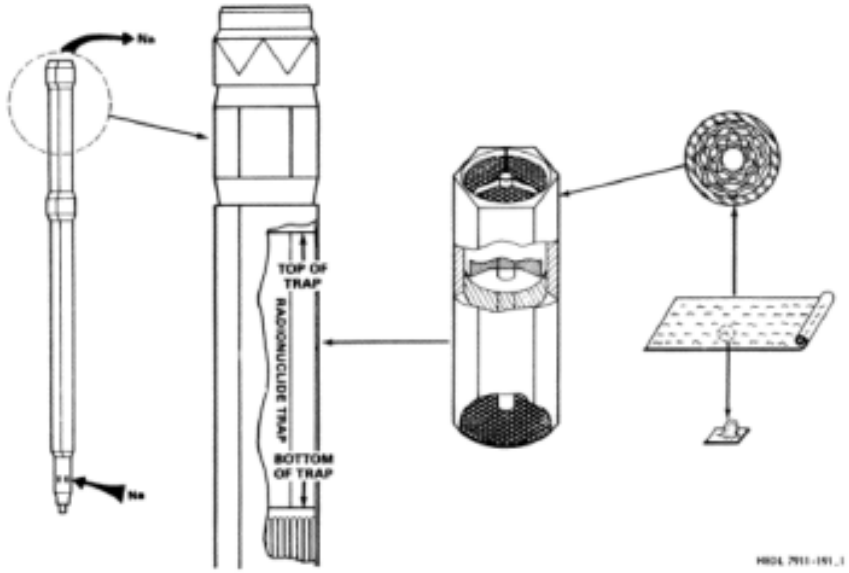
Ref: Redon B., *Etude et modélisation du piégeage sur matériaux carbonés du césium 137 lors de la purification du sodium primaire des réacteurs à neutrons rapides*, Thèse de doctorat de l'INPG, 11.09.**1998**

Activated Corrosion Products Trapping

Operational feedback in Germany:
Ex : ^{54}Mn, ^{65}Zn 50h in Na at 360°C 1mmNi : 83kBq/cm^2

Operational feedback in France : loop TPL SILOE,
and in Belgium : BR2

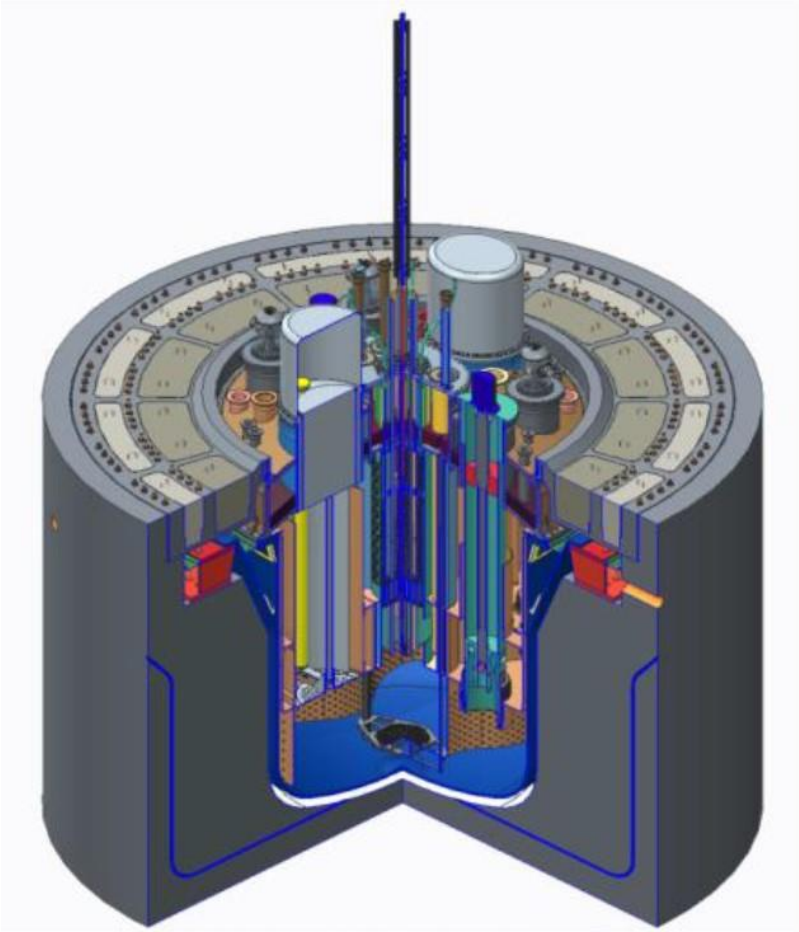
Nickel foil for ^{54} Mn (tested in EBR2) (mounted in Fuel Assembly above pins. Less efficient for ^{60}Co



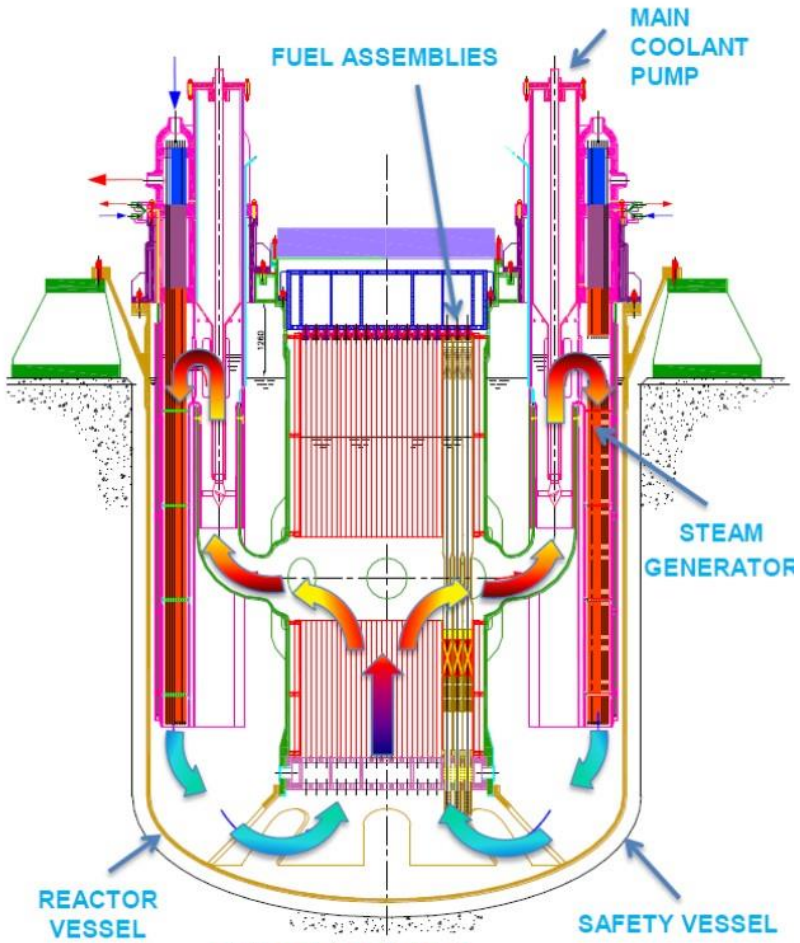
Up to now, not mandatory for SFRs
To be investigated for longer operation, i.e. 60 years?

Heavy Liquid Metal Systems (Pb, Pb-Bi)

Heavy Liquid Metal Systems

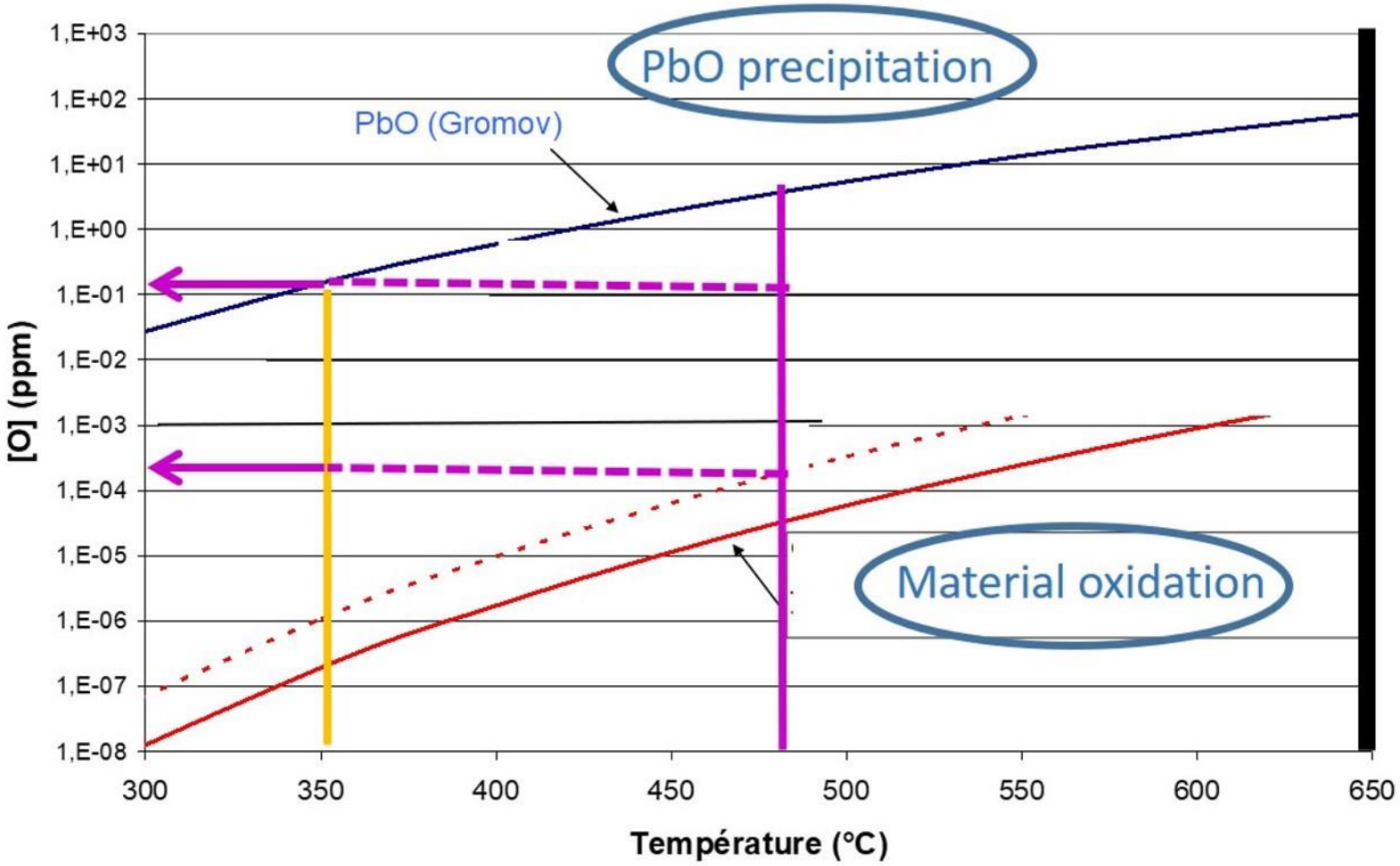


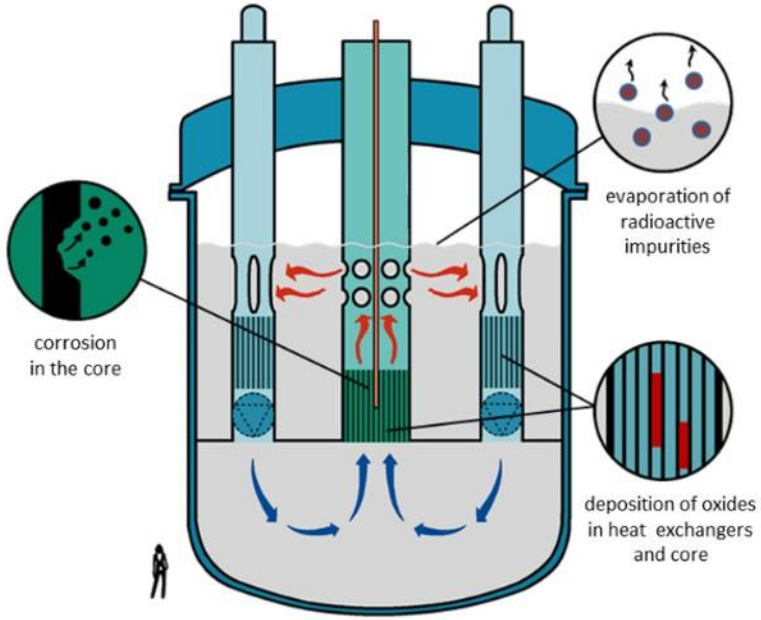
MYRRHA (ADS)
Coolant: LBE
Courtesy: SCK-MOl



ALFRED (LFR)
Coolant: Lead
Courtesy: Ansaldo Nucleare

[O] « working » area for LFR





Courtesy SCK-MOl

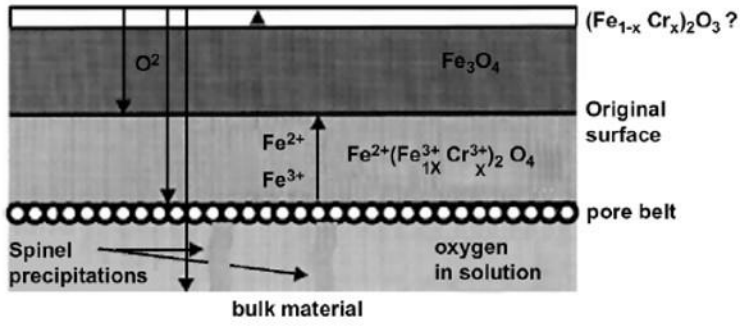
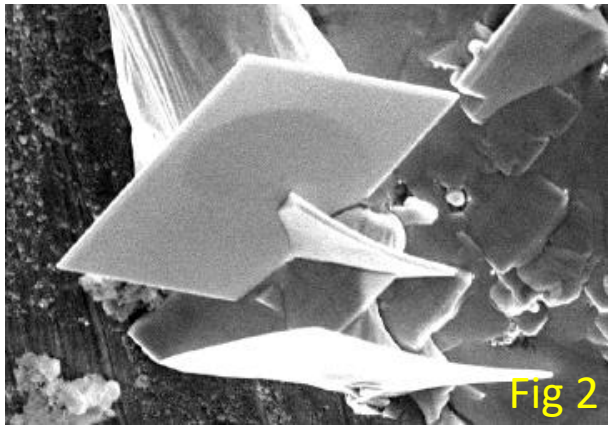
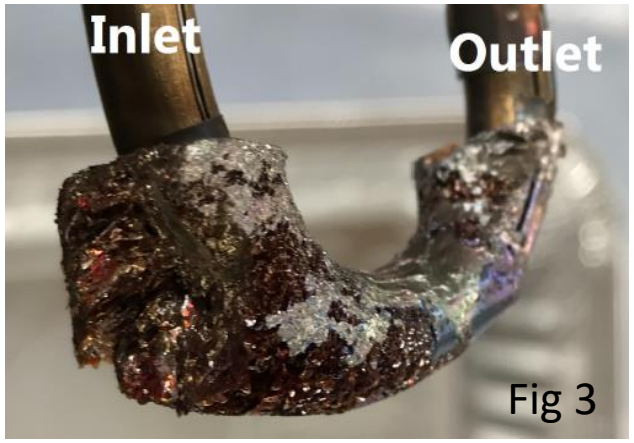


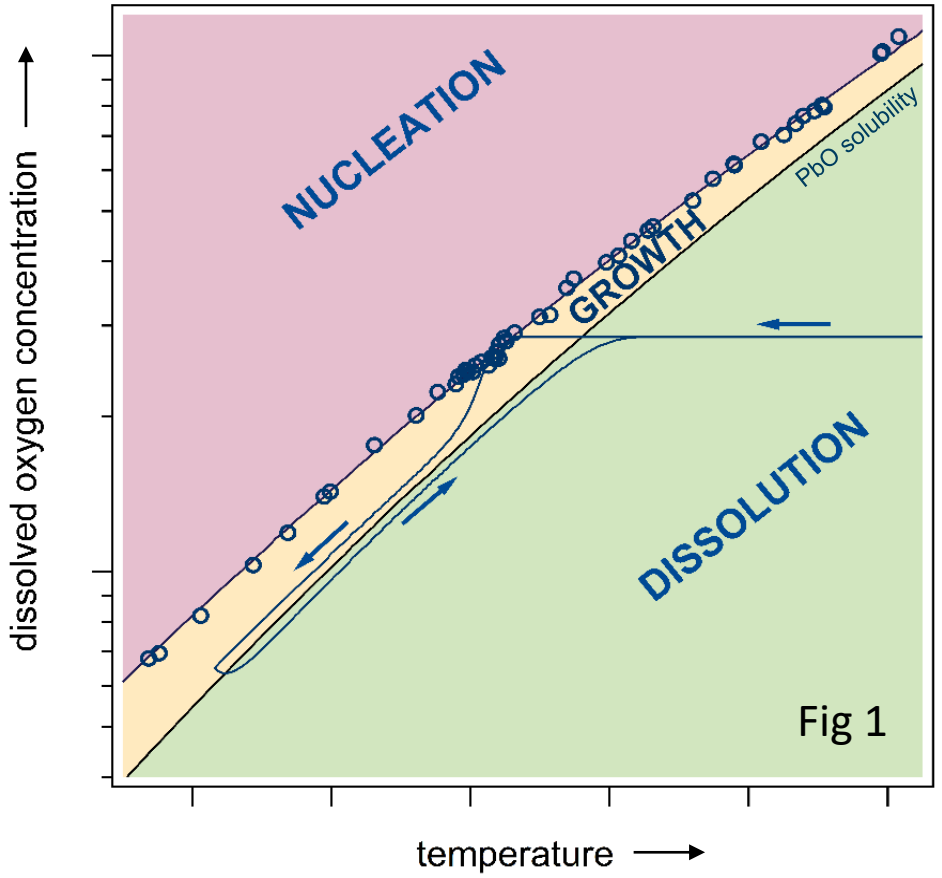
Diagram [O]-T (Courtesy SCK PhD K Gladinez SCK-Mol Univ Gent (19-09-2019)

Main results:

- Metastable field: possibility to nucleate, then to favour crystal Growth (Fig 1)
- Nucleation in LBE bulk (particles) or on metallic cooled surfaces (Fig 2), then growth (Fig1).
- Very limited dissolution rate of PbO particles (compared to Na due to its reducing properties): necessity to perform CFD calculations to follow particles then to find the best location for a « cold trap ».
- Possibility to foresee the use of a cold trap which includes cooling to increase supersaturation and promote homogeneous nucleation then filtering area (packing).
- Possibility to favour heterogeneous nucleation on cold walls (Fig 3):
  - ➔ to be investigated deeply.
  - ➔For Na: cold trap includes cooling to increase the supersaturation then packing implemented to provide heteregeneous sites for nucleation then to act as « seeded » surfaces for growth.







These data will allow SCK to design efficient purifications devices.

Ref: Gladinez, K., Rosseel, K., Lim, J., Marino, A., Heynderickx, G., & Aerts, A. (2017). Nucleation and growth of lead oxide particles in liquid lead-bismuth eutectic. *Physical Chemistry Chemical Physics*, *19*(40), 27593-27602.
Ref: Gladinez, K., Rosseel, K., Lim, J., Marino, A., Heynderickx, G., & Aerts, A. (2017). Determination of PbO fouling mechanisms (to be published in Nuclear Engineering and Design)

Previous R&D

- **Filtering:** metallic mesh, dynalloy, sintered filter
- **Filtration efficiency depends on :**
  - Liquid metal properties (viscosity, density,..)
  - Particles : nature, form, size, concentration
  - Temperature
  - Flow velocity
  - Filters medium characteristics (geometry, porosity, pressure drop...)
  - Its location in system
- Best results obtained with Dynalloy filter (100μm mesh, metallic textile)

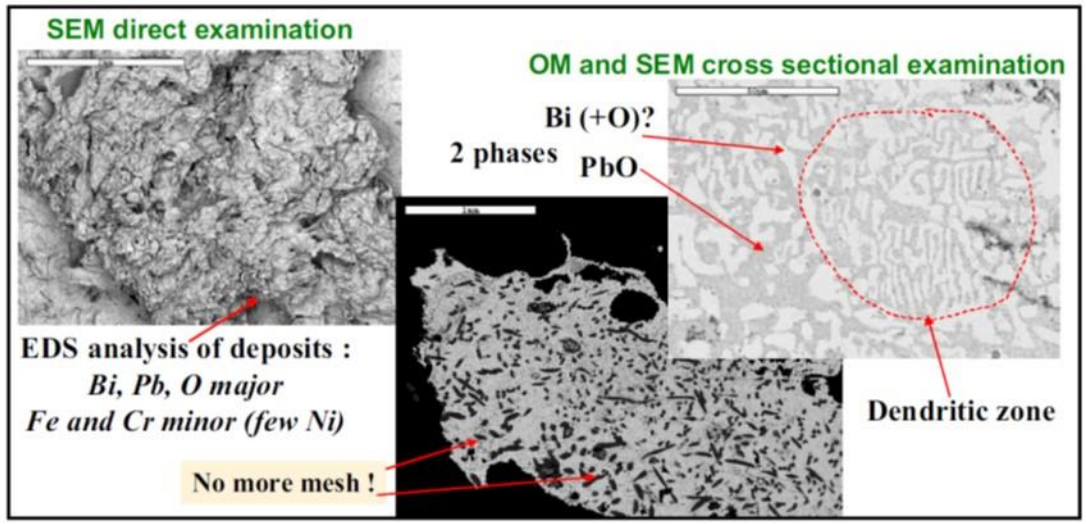
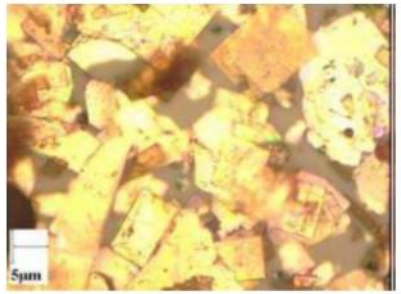
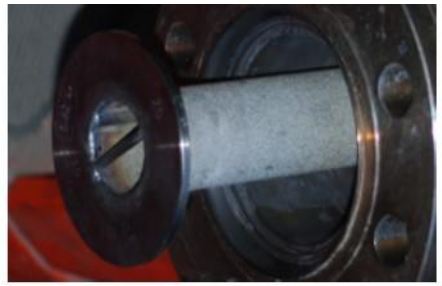


Figure 6: Dynalloy filter N°9 characterization





Sintered filter « Poral »

Dynalloy

Pall cartridge

Ref: EUROTRANS-DEMETRA project D57 O Morier, F. Beauchamp, L. Brissonneau CEA 2009

Thank You for Your Kind Attention

GEN IV International Forum SM

Upcoming Webinars

23 October 2019	Passive Decay Heat Removal System	Dr. Mitchel Farmer, ANL, USA
13 November 2019	Czech Experimental Program on MSR Technology Development	Dr. Jan Uhlir, Research Center Řež, Czech Republic
18 December 2019	TRISO Fuels	Dr. Madeline Feltus, DOE, USA