Treatment of Irradiated Graphite to Meet Acceptance Criteria for Waste Disposal

A New IAEA Collaborative Research Programme

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250,000 tonnes world-wide...

- Graphite is a significant radwaste stream, originating primarily in the United Kingdom, the former Soviet Union countries, and France – the major developers of graphite-moderated reactor technology.
- Taking the UK as an example: has around 80,000 tonnes of moderator or reflector material from a total of 47 reactors, principally from Magnox and Advanced Gas-Cooled Reactors

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UK: GLEEP

A small research reactor operated at extremely low power, and dismantled ‘by hand’

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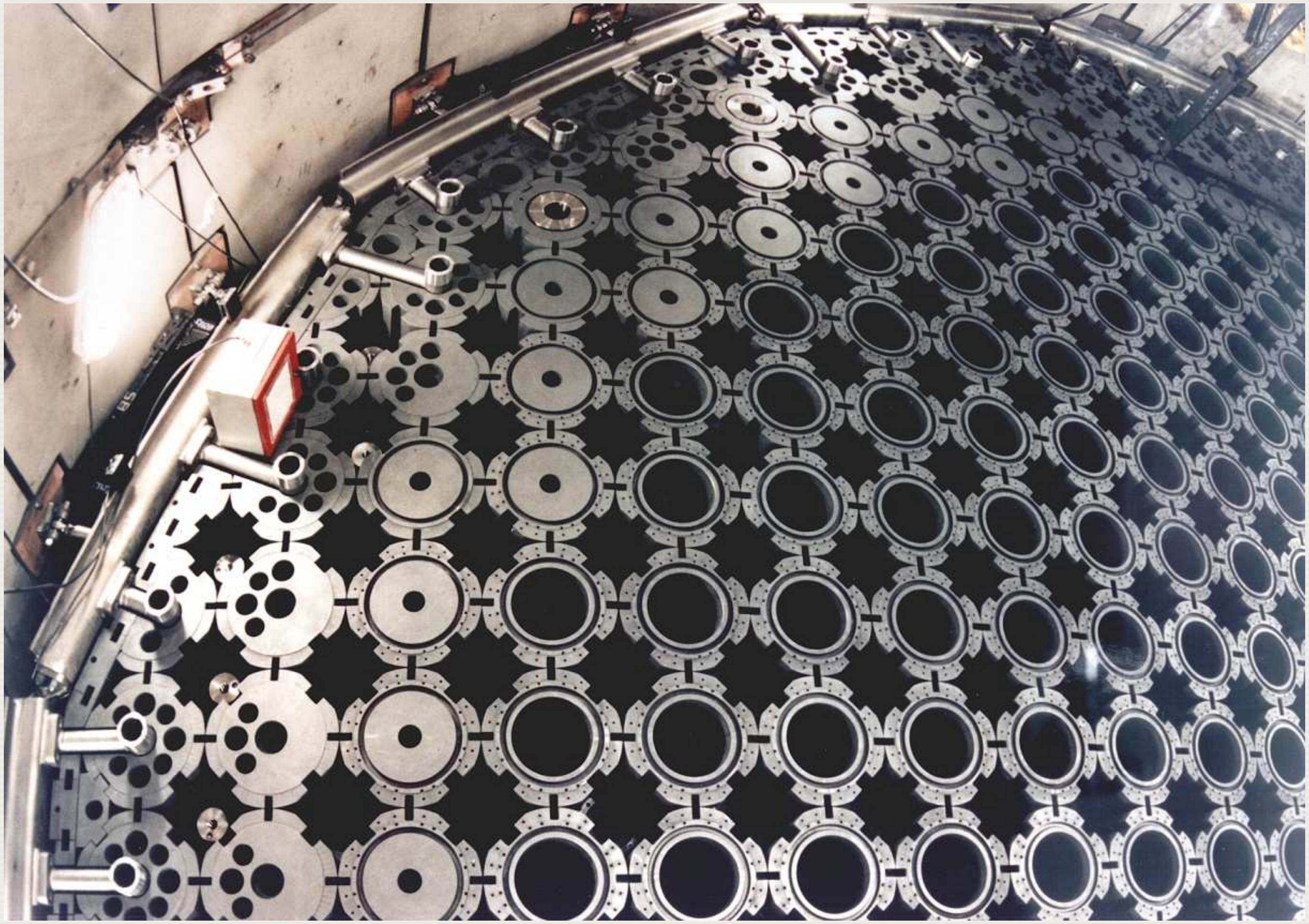
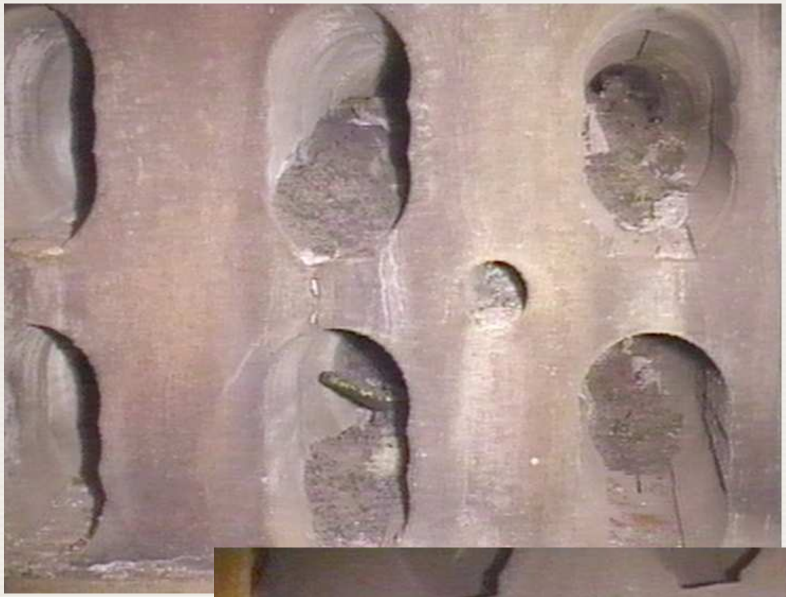
UK: Advanced Gas-Cooled Reactor



Commercial power reactor

UK: Windscale Pile 1

Discharge face
before the 1957 fire...



...and after

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Gas-Cooled Reactors...

- In these UK reactor examples, along with the French UNGG, British ‘Magnox’, and similar designs in Italy (Latina), Japan (Tokai 1) etc., the graphite has been in contact with the coolant which can transport material to the core which may become activated. A possibility of contamination from failed fuel also exists although, in general, this has been of low significance.

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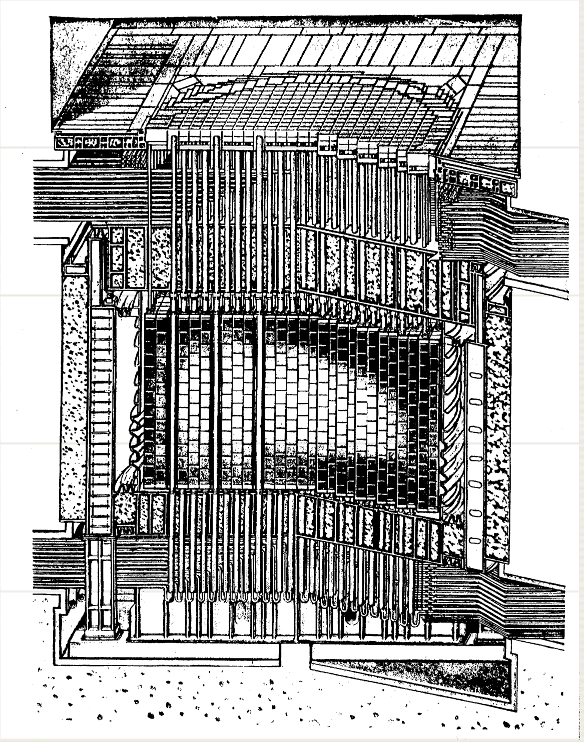
Water-cooled graphite moderated reactors...

- Early US development plant at Hanford, and most ex-Soviet graphite reactors are of this type.



The orientation of fuel tubes varies between US and Soviet designs. The early Soviet production reactors were very basic and serious contamination of graphite by fuel debris has occurred: also a special case is the Beloyarskaya design, where fuel had integral cooling tubes and where there were many failures.

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Member State Approaches to the Graphite-Waste Issue:

- There has been no consistent approach.
- Options are:
  - 'Safe Storage' in reactor vessels or containments
  - Progress with deep repository construction
  - Case for shallow repository disposal
  - Do nothing!
  - Think laterally... Perhaps utilise the unique chemical/physical/mechanical properties of graphite

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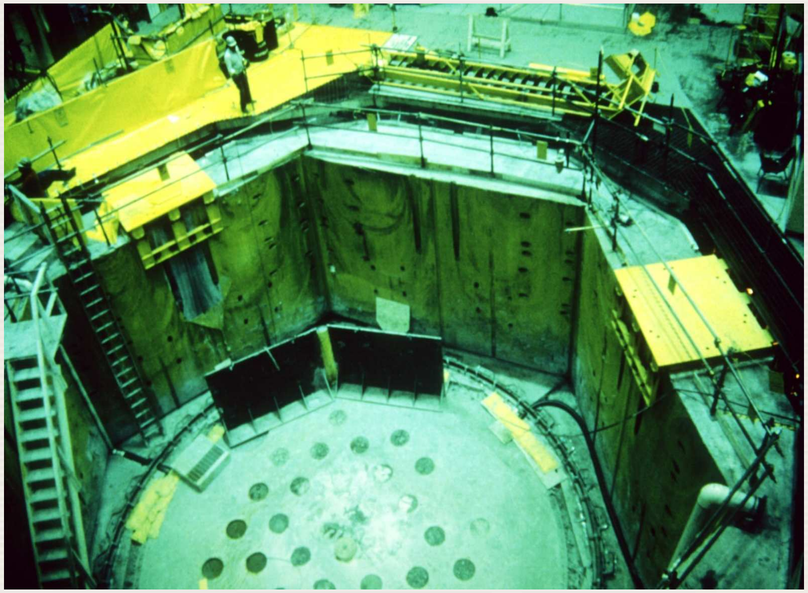
Successful graphite-stack dismantling (1):

- Fort St. Vrain, USA (HTR) – under water



- Windscale prototype AGR (UK) – in air

(also GLEEP, in air, as shown already)

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Successful Graphite-Stack Dismantling (2)

- Brookhaven Graphite Research Reactor (USA) – using viscous sprays and 'mechanical recovery'

Note that this stack contained significant Wigner energy, but measurements and an independent safety assessment by one of the present authors (AJW) proved that there was no safety hazard.

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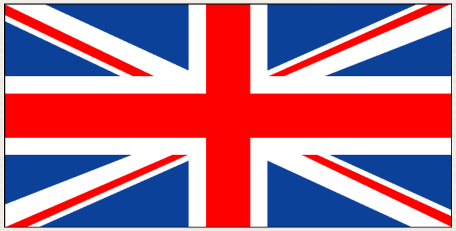
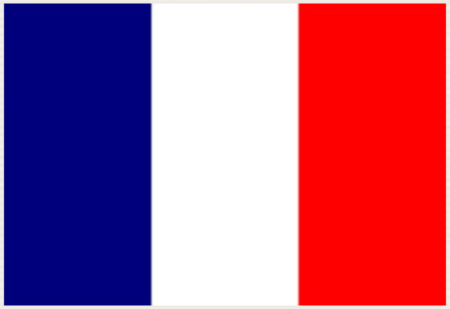
National Strategies for Graphite (1)

- ***United Kingdom***: Primarily considering a deep repository ('GDF'); a shallow burial option was considered for some fuel-sleeve graphite but not followed up: mechanical dismantling after lengthy safe-storage is the present intention, and there is minimal support for research into alternative strategies.



National Strategies for Graphite (2)

- ***France:*** Official strategy is for a shallow site for ‘graphite and radium-bearing wastes’: however, this has run into difficulties and a deeper site is now under consideration. Very recently it has been confirmed in industry meetings that alternative strategies for graphite treatment and disposal are back on the agenda.



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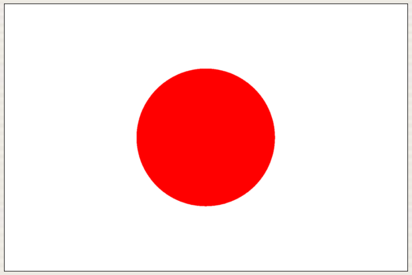
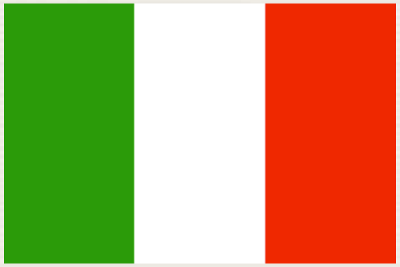
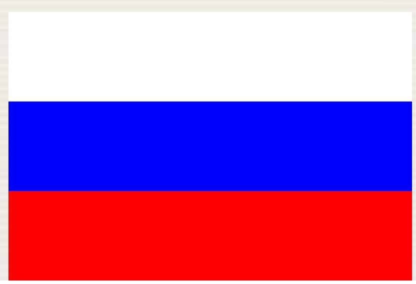
National Strategies for Graphite (3)

- ***Japan (Tokai 1):*** Present plan unclear to this author after initial interest in incineration for some of the material (fuel sleeves and reflector at least) mitigated by concerns about ^{14}C releases;
- ***Italy/Spain:*** One ‘Magnox’ type reactor each: likely to follow French or UK strategy.


National Strategies for Graphite (4)

- ***Russia:*** No established plan beyond 'safe storage' on reactor sites: however, it was recently stated at IAEA CRP that incineration of the graphite in a remote location after mechanical dismantling was now under consideration
- ***Ukraine (Chernobyl)****:* Clearly a special case: the graphite from the damaged core has special issues, and a plan for mechanical dismantling of the undamaged reactors has been prepared;



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National strategies for Graphite (5)

- ***Lithuania (Ignalina):*** Active discussion of options, and preparations, in response to EU obligations, and also the desire to re-utilise the site (and the incumbent workforce) for a new plan:

  <u>HOPEFULLY WILL BE THE 'LEAD' IN DISMANTLING A FULL-SIZE COMMERCIAL REACTOR</u>

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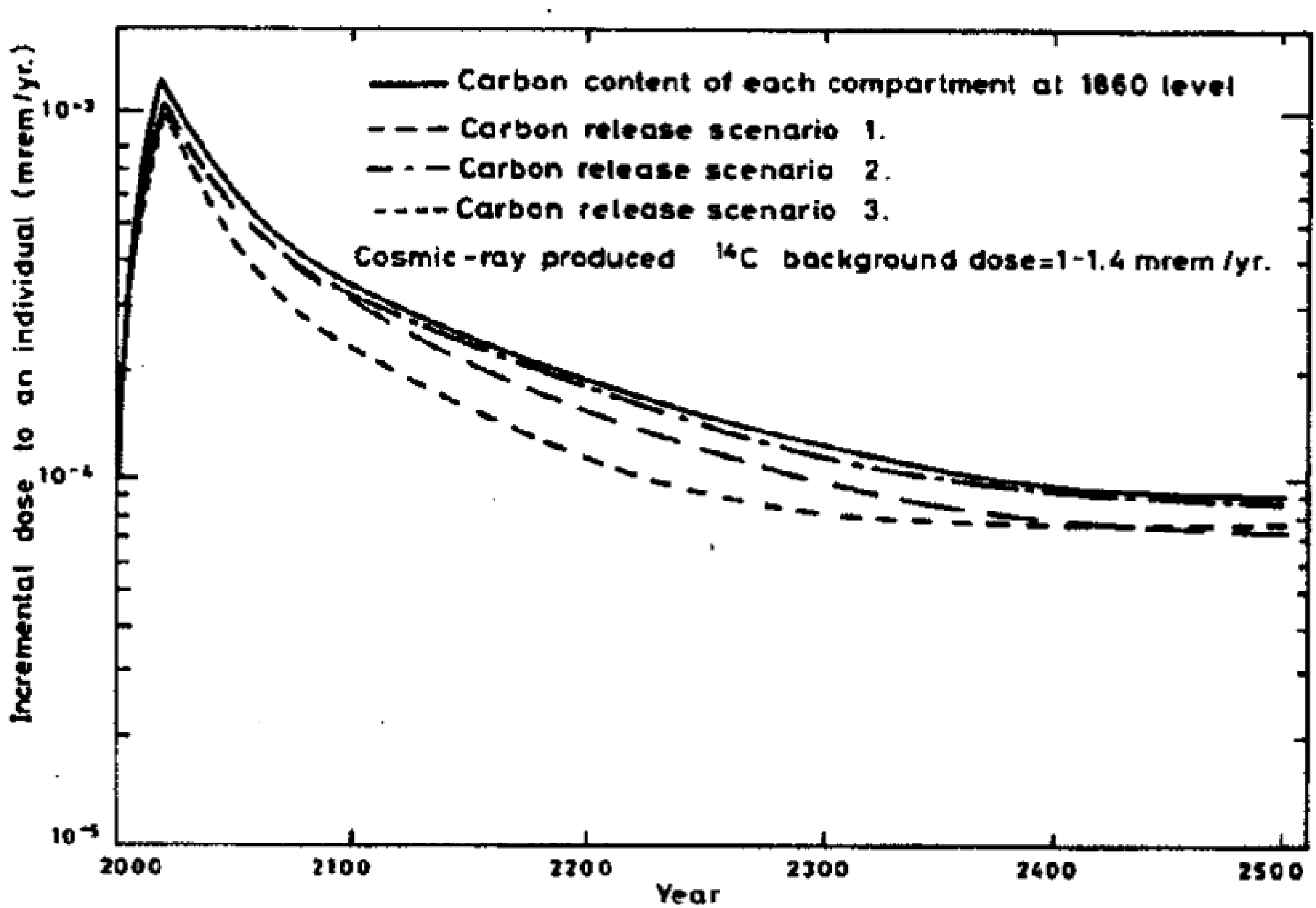
Different national regulations lead to different concerns over graphite radwaste:



More on ^{14}C and ^{36}Cl

- **^{14}C** can potentially be released as CO, CO_2 or CH_4 and it is the last of these which is generally perceived as the greatest risk through its ability to enter the food chain.
- **^{36}Cl** is considered a risk for the same reason.
- Half lives: ^{14}C: 5760 years; ^{36}Cl: 301,000 years: whilst the long times are thought of as prolonging the hazard, they imply very low Bq

"No-one is ever going to be killed by ^{36}Cl..."
Hans Forsström

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IAEA Role

- The IAEA does not seek to influence national policy in this area, but to *inform*...

  ... hence the establishment of a Collaborative Research Programme to collect the best advice and experience

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CRP Aims

- a significant reduction in waste volume or packaging requirements;
- pre-treatments which either reduce significantly the radioisotope content of the material, or facilitate other processing options, or both;
- a significant cost saving, either through operational efficiencies or by allowing a useful product or products to be recovered from the material;
- a favourable timescale (earlier option to achieve some disposal result which would otherwise be delayed).

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CRP Directions

- Direct chemical or physical treatment of graphite leading to its disposal in an alternative form to solid graphite, with economic and long-term radiological benefits;
- Pre-treatment of graphite ahead of other disposal or innovative treatment, usually in order to reduce the radio-isotope content and to facilitate the economics and radiological safety of the following process operations;
- Treatment of the products of innovative process to improve radiological safety or for economic improvement (such as separation and recycling of useful isotopes for the nuclear and/or medical industries).

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CRP Participants

- Lithuania (LEI and Ignalina NPP)
- France (EdF CIDEN, CEA, ANDRA, IPNL)
- Germany (FZJ, FNAG)
- USA (Idaho State University)
- UK (NDA, Manchester University, Sheffied University, Bradtec/Costain/Studsvik UK/Hyder)
- Spain (ENRESA)
- Russia (A.A. Bochvar High-Technology Research Institute, Rosenergoatom [planned])
- Ukraine (Inst. Environmental Geochemistry, Inst. For Safety Problems in NPP)
- Switzerland (Paul Scherrer Institute)
- China (INET, Tsinghua University)

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Directions

- Improving techniques for isotopic characterisation;
- Methods for ‘cleaning’ of graphite to be evaluated (reduction of radio-isotopic content and/or, where relevant, other toxins such as heavy metals);
- Isotope separation techniques, to include thermal diffusion, pressure-swing absorption, centrifuging and cryogenic methods, for all relevant isotopes;
- The philosophy of ‘dilute and contain’ for treatment of specific isotopes such as C-14;
- Novel handling methodologies which facilitate alternative treatments (*e.g.* graphite removal as crumbled and vacuumed particulate, transfer in liquid foams, etc.).

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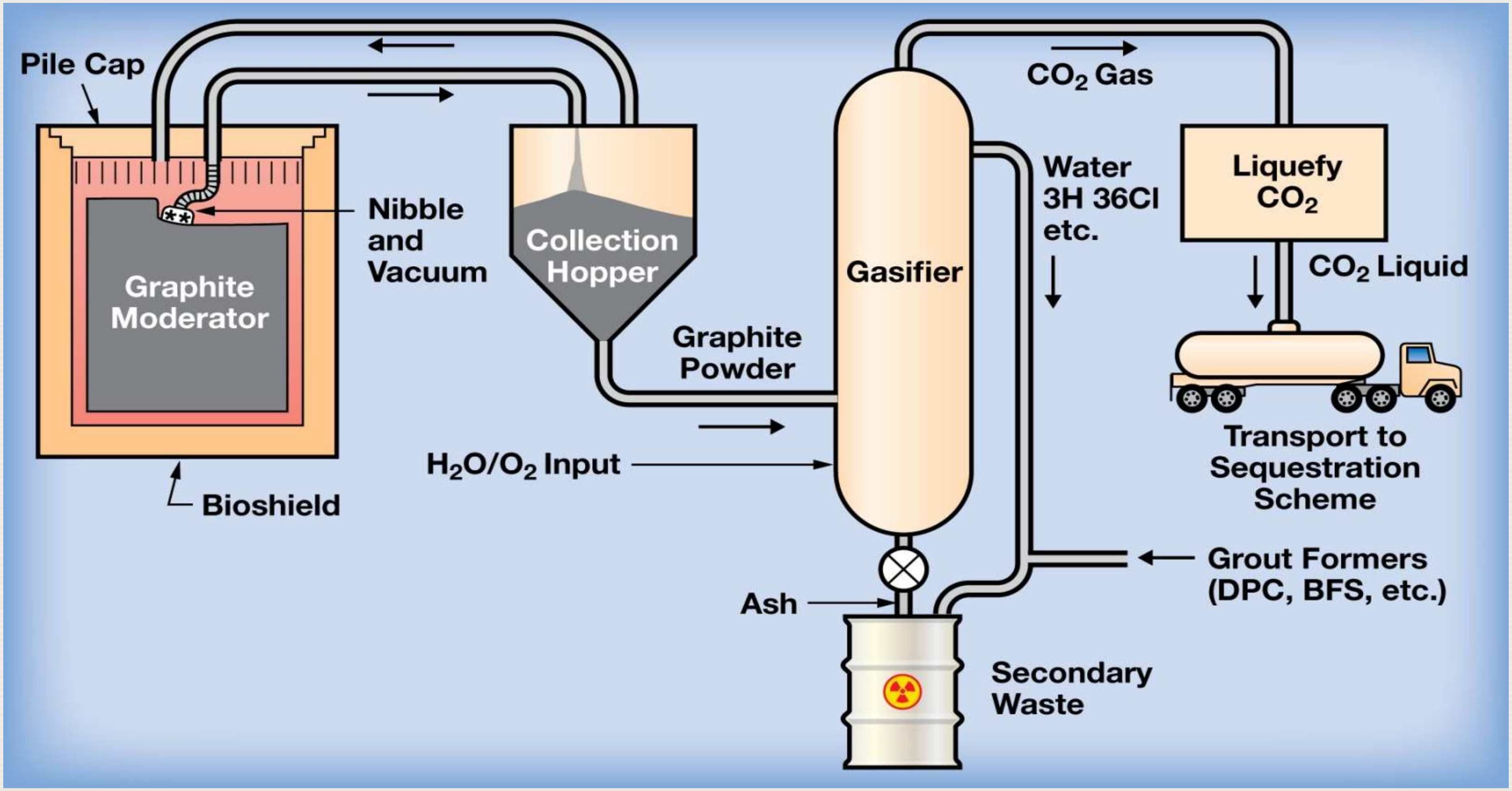
Example of Innovative Linked Technologies under Consideration (Braqdtec/Hyder/Studsvik UK/Costain)



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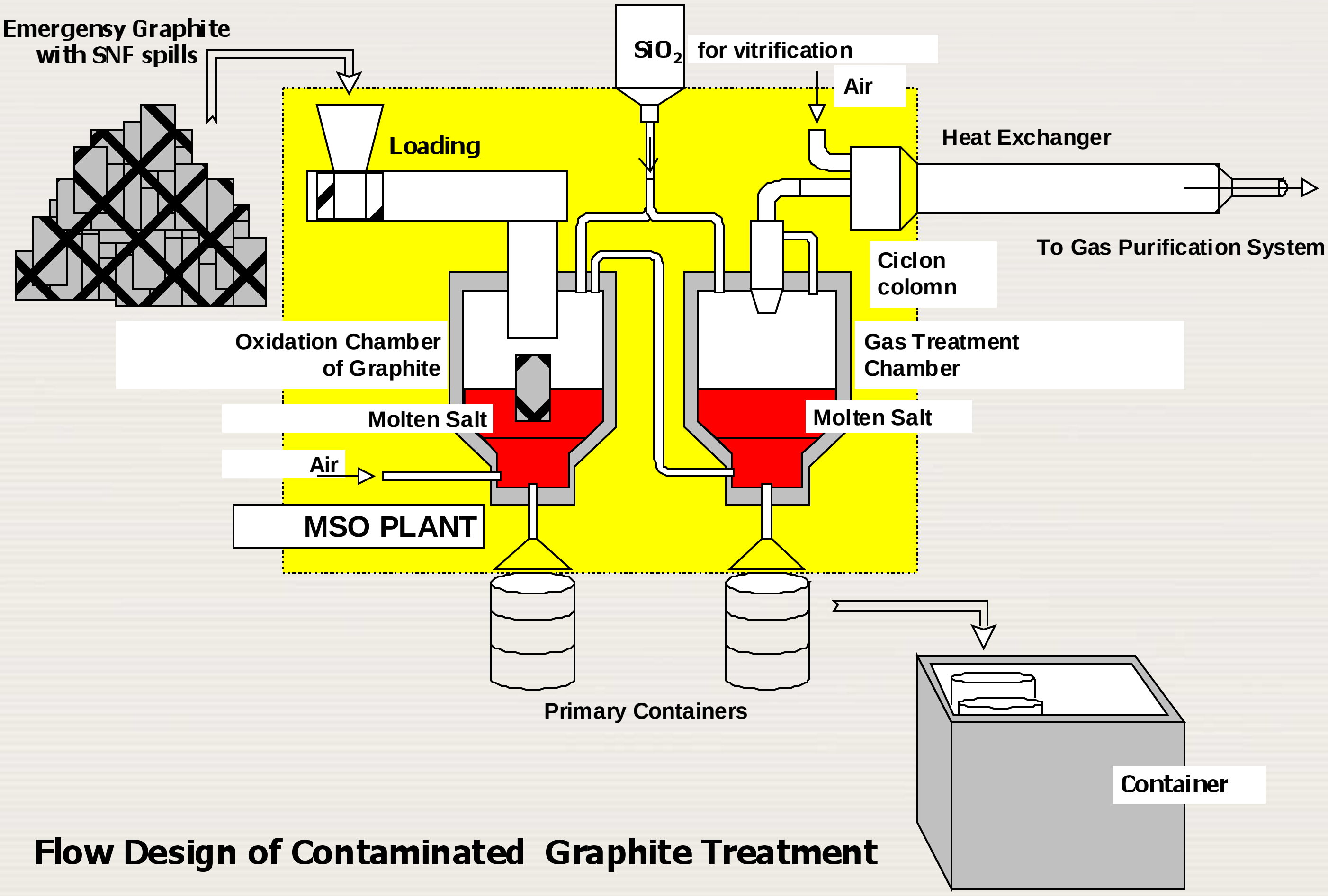
2nd Example: Molten-Salt Technology for Immobilising Highly Contaminated Graphite (Nikiet/Rosenergoatom)



Flow Design of Contaminated Graphite Treatment

CRP Timescale and Output

- Planned to complete work in 2015
- IAEA TECDOC to be produced *(participants' IPR is protected)*

Thank you for your attention