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International Perspective on non-HEU Mo-99 Production

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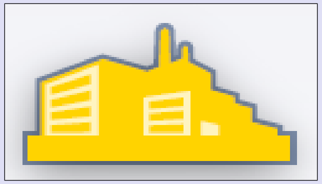
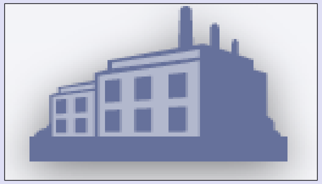
Major facilities in the global supply chain of Mo-99

Mo-99/Tc-99m Supply Chain



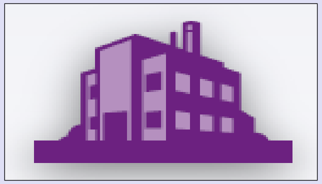
Reactors

Reactors produce Mo-99 raw material using Uranium-235 targets



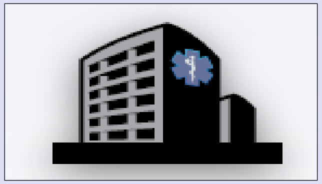
Mo-99 Processing Facilities

Processors purify the Mo-99 raw material to produce processed Mo-99



Tc-99m Generator Facilities

Generator manufacturers produce Tc-99m generators from processed Mo-99



Hospitals and Pharmacies

Use Tc-99m generators to perform nuclear medicine procedures

Target and fuel manufacture

WASTE Facilities

Current Supply Chain and its Challenges

- There has been a large volume of work undertaken to provide clarity of current challenges for the supply chain:
  - NEA High Level Group has done excellent work on security of supply
  - IAEA technical programs have given insights into manufacturing issues

- The significant challenges which have been identified include:
  - Aging reactor fleet
  - Distortions in the elements of cost recovery
  - Future options for improved economics in the supply chain

Production Methodology

- The vast majority of Mo-99 is produced from the fission of uranium
- In recent years there has been a large amount of interesting and innovative work undertaken on alternate methodologies
  - Accelerator based systems
  - Solution reactor
  - New and improved techniques for neutron activation of Mo-98
- This work is useful in that it allows estimates of technological maturity and review of the potential costs of alternatives to Mo-99 production in reactors.

Looking Forward

- In the short term reactor based production is likely to remain the mainstay
- However, the challenges of introducing new manufacturing capability associated with newer reactors based on complete elimination of HEU from fuel and target plates remains a challenge
- The challenge is exacerbated by continued distortions and a lack of transparent full cost recovery in the major marketplaces

Major restraints – HEU to LEU conversion

- Converting existing Mo-99 production from HEU to LEU targets involves substantial up-front costs.
- Converting HEU facilities to LEU requires long lead times
- Difficult licensing processes for both nuclear and medical licencing.
- Conversion to LEU (using current target technology) reduces capacity.
- Issues of increased wastes with the use of LEU targets.

Australia’s Position

- Australia has made a significant national investment in the Open Pool Australian Light Water multipurpose reactor and a Mo-99 production facility
- OPAL first went critical in 2006
- Mo-99 plant commissioned in 2008

OPAL research reactor

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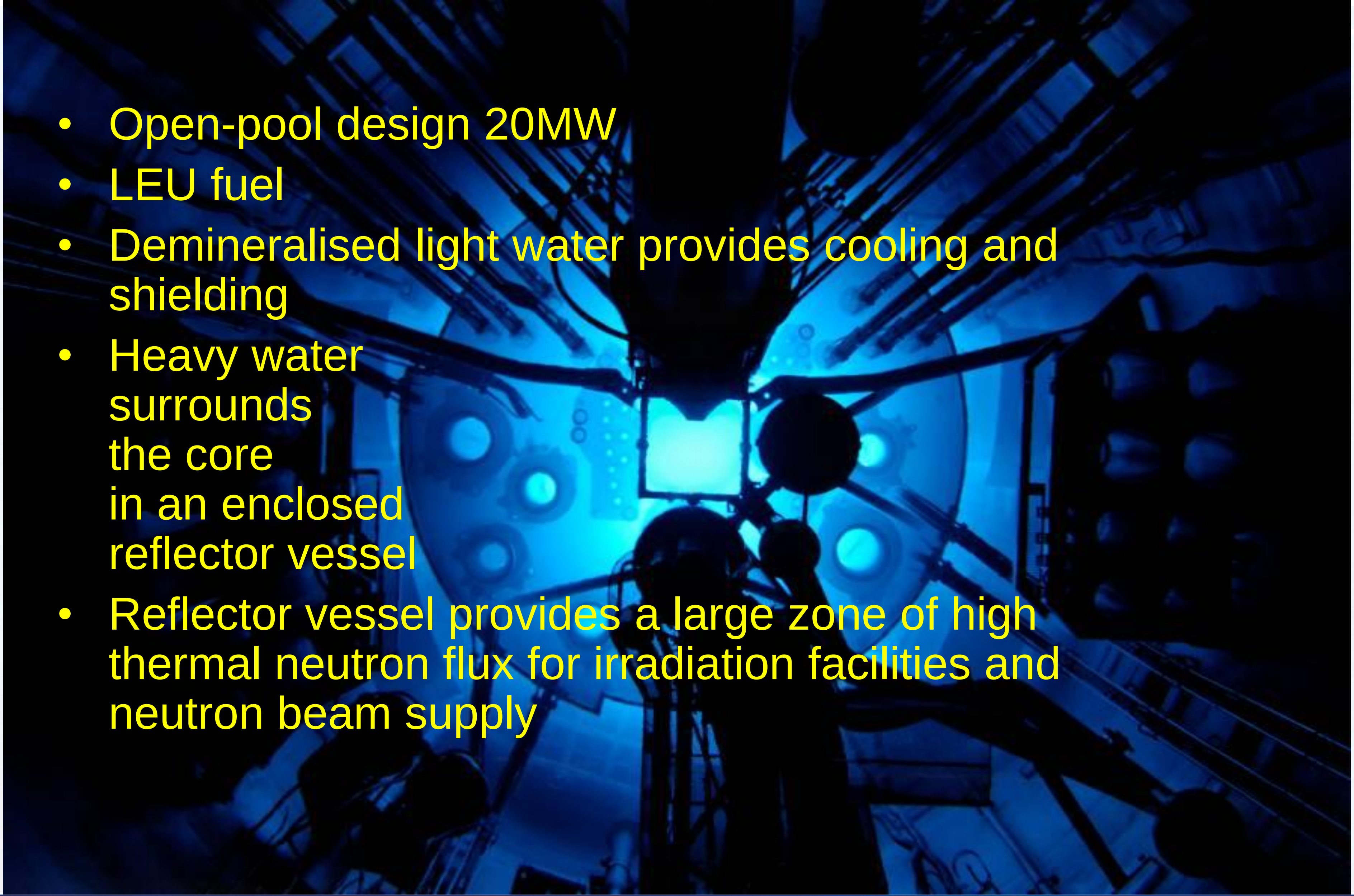
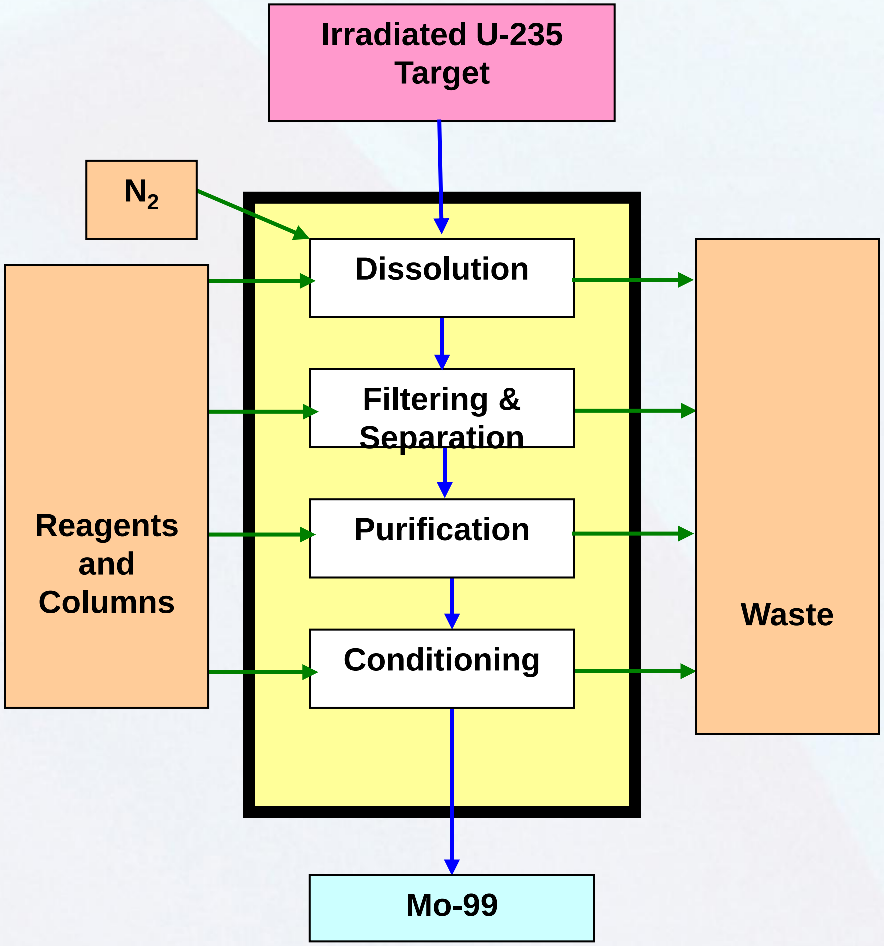


- Open-pool design 20MW
- LEU fuel
- Demineralised light water provides cooling and shielding
- Heavy water surrounds the core in an enclosed reflector vessel
- Reflector vessel provides a large zone of high thermal neutron flux for irradiation facilities and neutron beam supply

OPAL research reactor

Current LEU Mo99 Production at ANSTO

- **Target**
  - Al clad UAl dispersion flat plate target
  - 19.75% enriched U
  - Irradiated at 9×10^{13} $n/cm^2/s$ for 3-10 days
- **Process**
  - Plates dissolved in sodium hydroxide
  - Uranium precipitates and captured in filter
  - Dry filter cakes stored in non-critical array
- **Separation**
  - ion exchange & successive purification steps



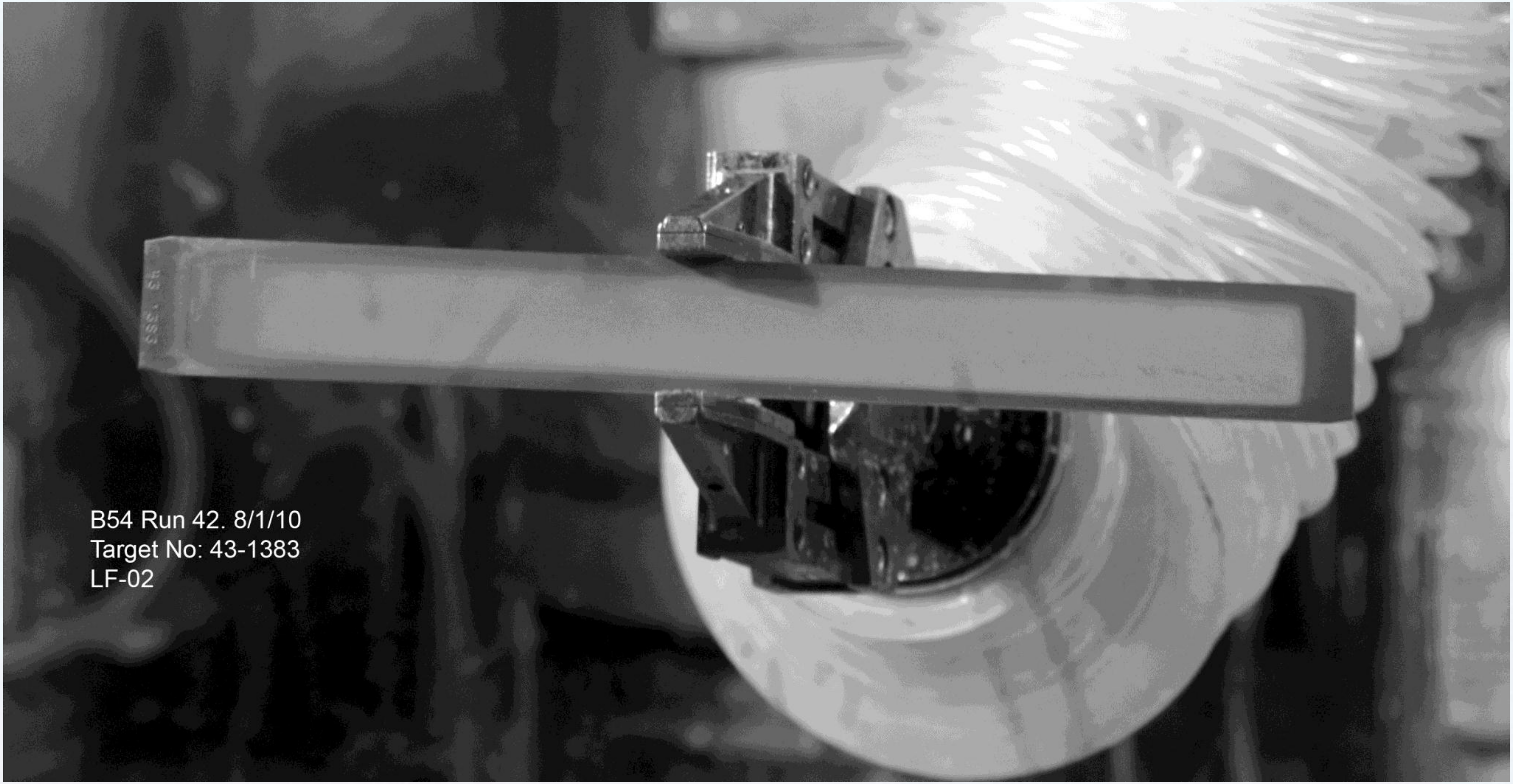
ANSTO's Mo-99 Plant

- Initially built to supply Australia and small regional markets
- Following supply crisis capacity increased to **1000 Ci** per week
- Able to export significant quantities

The Use of LEU

- The use of LEU fuel and LEU target plates by Australia is in conformance with, and in support of, our commitment to the full removal of highly enriched uranium from all research reactors and the elimination of HEU in target plates for Mo-99 production

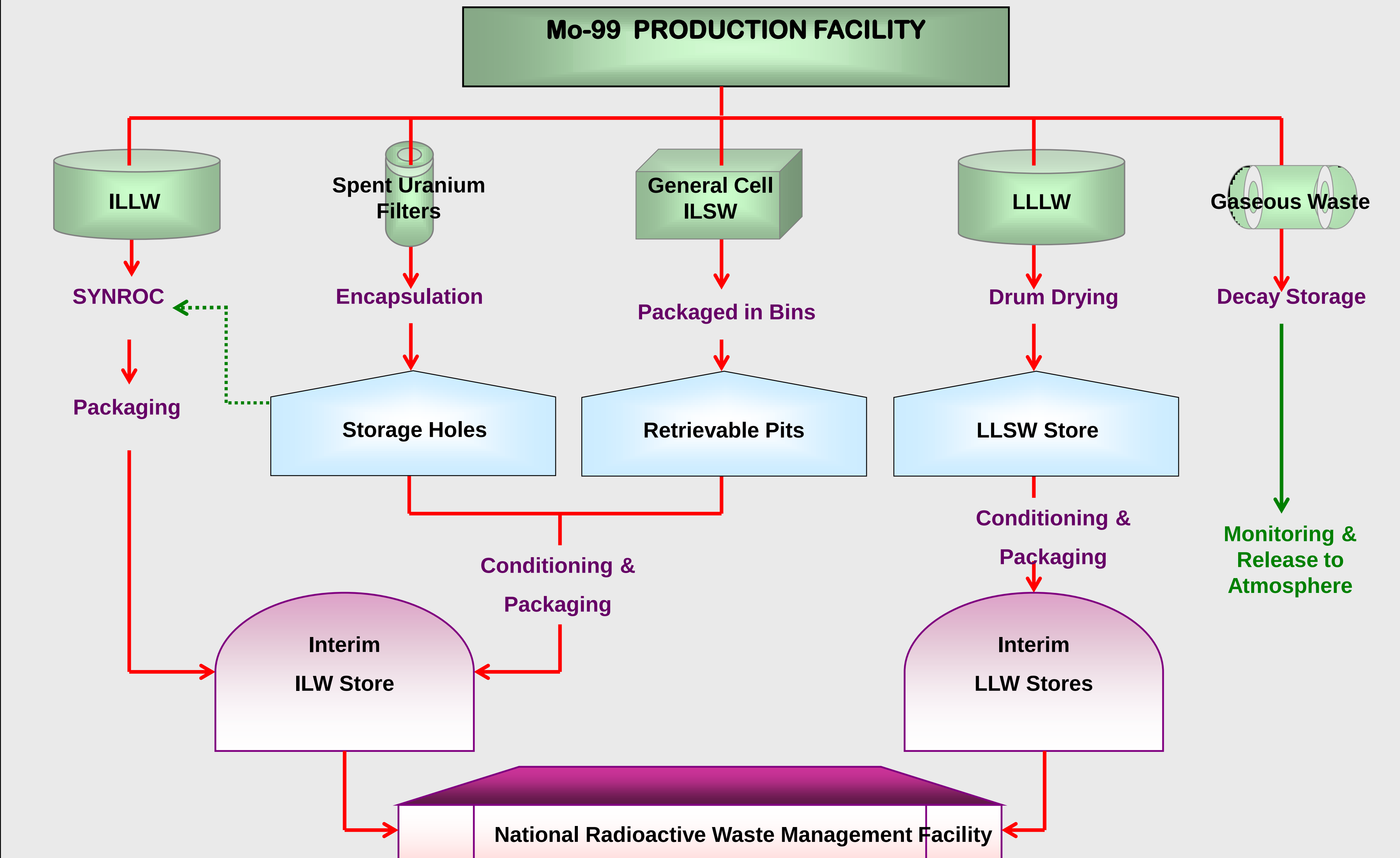
- We have demonstrated that high quality, compliant Mo-99 can be reliably produced using traditional techniques based upon LEU


B54 Run 42. 8/1/10
Target No: 43-1383
LF-02

Process Comparison

- HEU targets are typically 1.1-1.4 g/cc U in the “meat”
- LEU targets are typically 2.6 g/cc U in the “meat”
- Assuming HEU in 95% enriched and LEU is 19.75% enriched this gives approximately twice the amount of U in HEU targets as in LEU targets.
- This results in:
  - More targets required
  - More reactor volume required
  - More processing runs, capacity
  - More volume of waste produced.

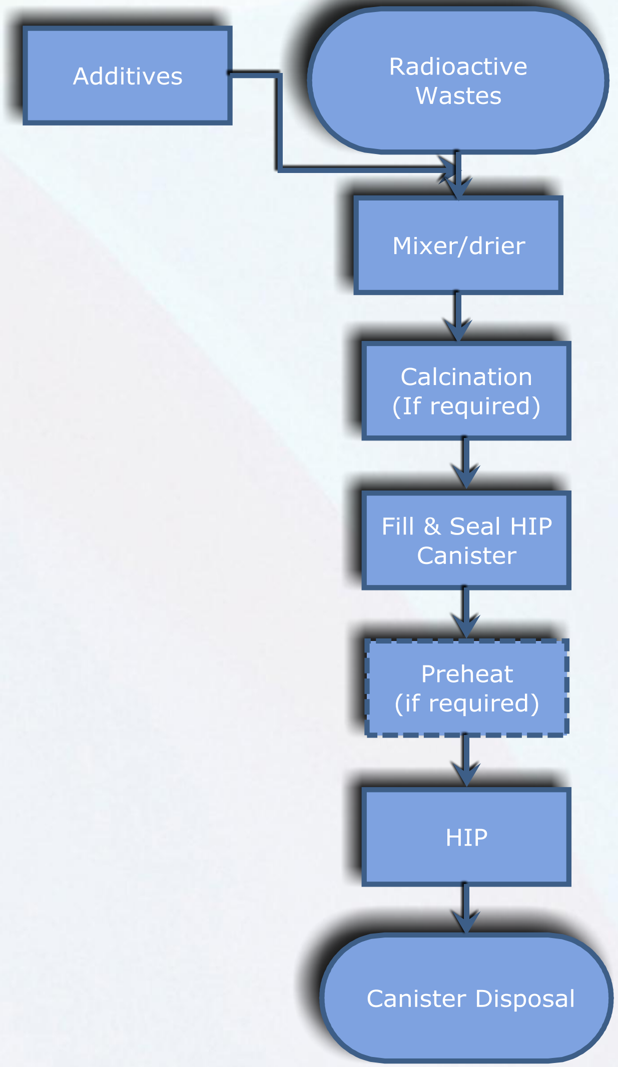
Waste Strategy



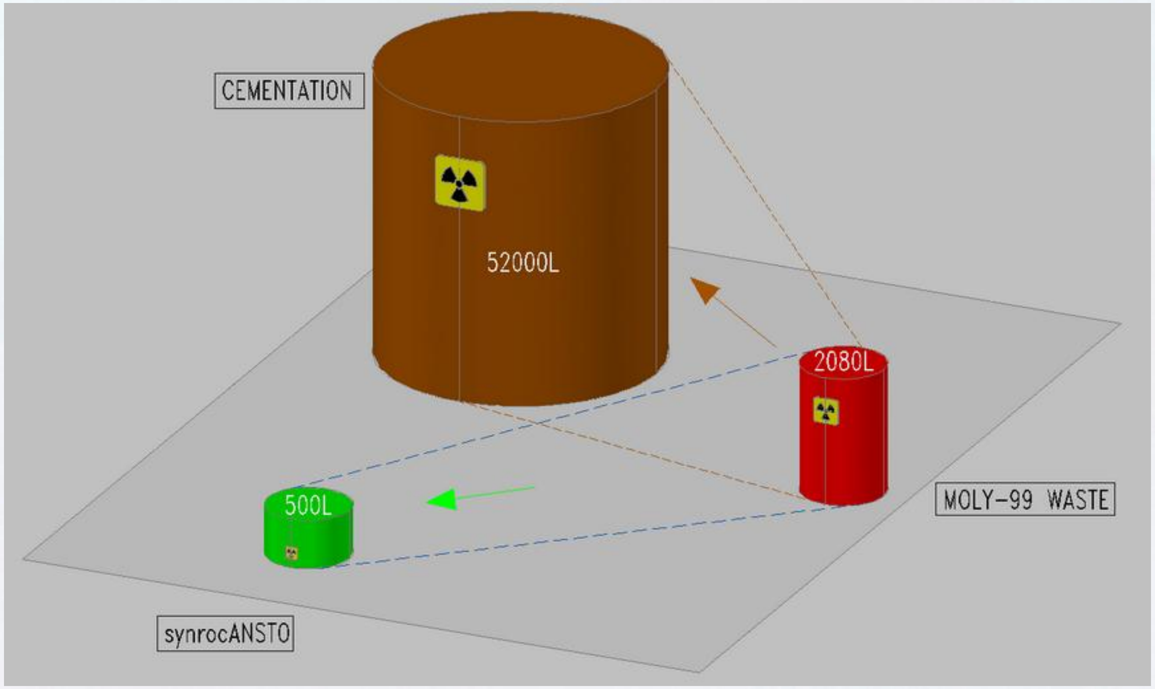
*synroc*ANSTO®

HIP Treatment Technology

- Mo-99 intermediate level waste will be treated in a new SYNROC facility
- It will then transferred and stored in an interim waste storage facility at Lucas Heights awaiting future transfer to a national waste repository.



Synroc
Comparison of Waste Volumes



Economics of LEU use

- We have been able to demonstrate from in-house economic analyses that have been independently verified, that it is possible to economically to produce Mo-99 and to anticipate the full disposition of waste from Mo-99 production without significant increases in the market price for Mo-99

Comments on Economic Study

- However, market prices are not yet subject to the discipline of proper cost recovery at all stages of production, and there is currently no agreed mechanism to charge for waste management.

- Australia takes the view that responsible and sustainable nuclear medicine production should include a costing approach that includes the disposition of wastes from the processing of Mo-99.

Future Production Distribution

- Investments in LEU-based reactor technology and scale-up of Mo-99 processing technology to provide robustness in the global supply has been under constant review by stakeholders globally over the last few years

- It is likely that a clearer view of future regional distribution of production will do more to mitigate fears of supply constraints when new investments are considered

Future Investment Requirements

- New investments require a predictable regulatory and non-proliferation regime especially to support full compliance
  - with the elimination of HEU
  - and provision for waste management in the nuclear medicine life cycle

- If the condition of predictability can be met and the condition of sufficiently distributed supply is met, the end user community will be able to make confident investments in the expansion of diagnostic capabilities and the associated training development of a new generation of nuclear medicine practitioners.

Looking Forward

- Short term actions, particularly associated with ageing reactors that do not meet the criteria established in international discussions may continue to have a distorting effect on the investment regime

- These short term actions can potentially create conditions of supply uncertainty that can negatively impact the confidence of the nuclear medicine community (and government stakeholders)

- It is therefore urged that efforts to eliminate HEU from fuel and target plates are intensified and that compliance suppliers and potential new investments are able to rely on a predictable environment to the greatest extent possible, both in the very short term and in the future ansto

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