Domestic Production of Mo99

Mo99 Topical Meeting
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NorthStar's Short Term and Long Term Solution

Short Term and Long Term Solutions

- Short Term Solution (mid-2012)
  - Missouri University Research Reactor -
    - Contract in place effective March 2011
    - It is expected that this solution will eventually be able to produce 50% of the US requirement
- Long Term Solution (2014)
  - NorthStar's LINAC methodology for the production of Molybdenum-99

- Once up and running both solutions will be used to supply not only the US market but also overseas.

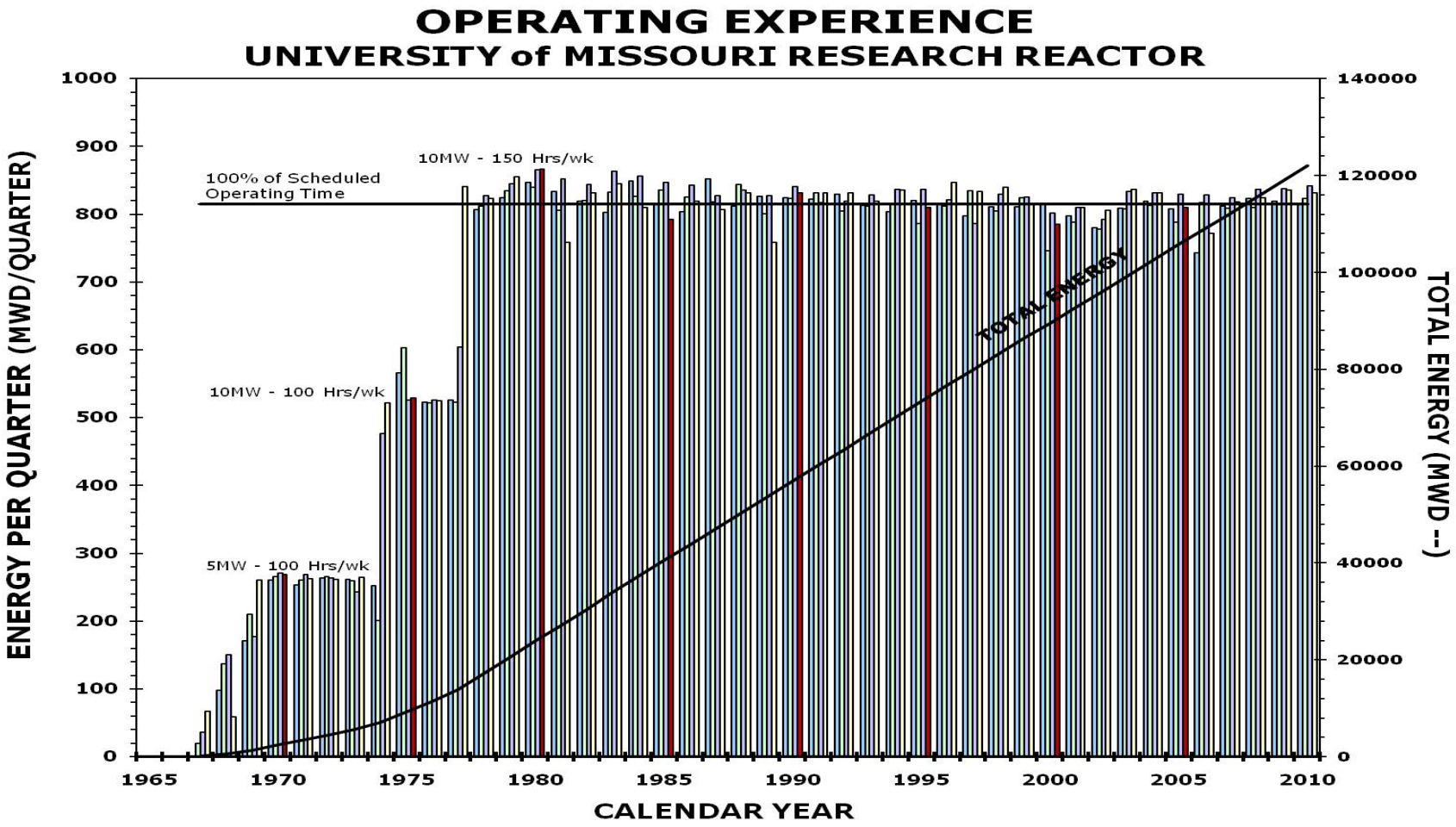
- These two approaches require NorthStar's TechneGen™ technology in order to guarantee success

Missouri University Research Reactor (n,γ)

Production of Mo99 via Reactor at MURR

- MURR has produced Mo99 previously in large quantities by the (n,γ) method,
- MURR has outstanding operational record,
- MURR/NorthStar production agreement announced March 1st,
- Production upon FDA approval,
- UPS Express Critical® to handle shipping to client pharmacies;
- Spent Mo99 solutions returned ground for recycle,
- MURR capable of producing up to 3,000 6-day Ci per week, and
- No licensing issues.

Production of Mo99 via Reactor at MURR



BEST SHORT TERM SOLUTION TO ESTABLISH SIGNIFICANT DOMESTIC MARKET SUPPLY WITHIN NEXT 6 MONTHS

LINAC Moly (γ, n)

Production of Mo99 via LINAC

- NorthStar has been active in this field since Nov 2007
  - NorthStar funded effort at RPI in early 2008 to validate the 1999 INL publication
  - Produced small quantities of Mo99 in that study and validated calculated estimates and experimental results were comparable
- NorthStar facility will house up to 16 LINAC machines capable of producing >3,000 6D Ci per week
  - SA of Mo99 ~10Ci/g potentially
  - one target set per day (~2,000Ci Mo99) processed
  - steady, redundant production on a daily basis
  - UPS Express Critical® to handle shipping to client pharmacies; spent Mo99 solutions returned for recycle
  - NNSA supported via Cooperative Agreement
- Facility location has announced - Beloit, WI
  - Located immediately adjacent to a new power substation being built with NorthStar requirements incorporated in the design - Location will have redundant power from two separate sources with automatic switching gear

Process Byproducts and Waste

Process Byproducts & Waste

- OECD Report clearly noted that costs of handling and disposal of waste will be added to the cost of Mo99 going forward

- FOA for NNSA Mo99 program clearly stated applicant could not assume DOE would take back the waste associated with LEU production.

- Both n,γ and γ,n Mo99 production processes by NorthStar use stable molybdenum isotopes as target material

  - Cost of disposal of NorthStar byproducts & waste is a small fraction of the total cost

NO URANIUM, PLUTONIUM, OR FISSION PRODUCTS ARE IN THE WASTE!

  - Bulk of NorthStar waste handled as DNS (recycle) allowing for Mo99 and Tc99m to decay away before disposal as a low level rad waste
    - NorthStar will remove long-lived Tc99 as part of recycle process

5.

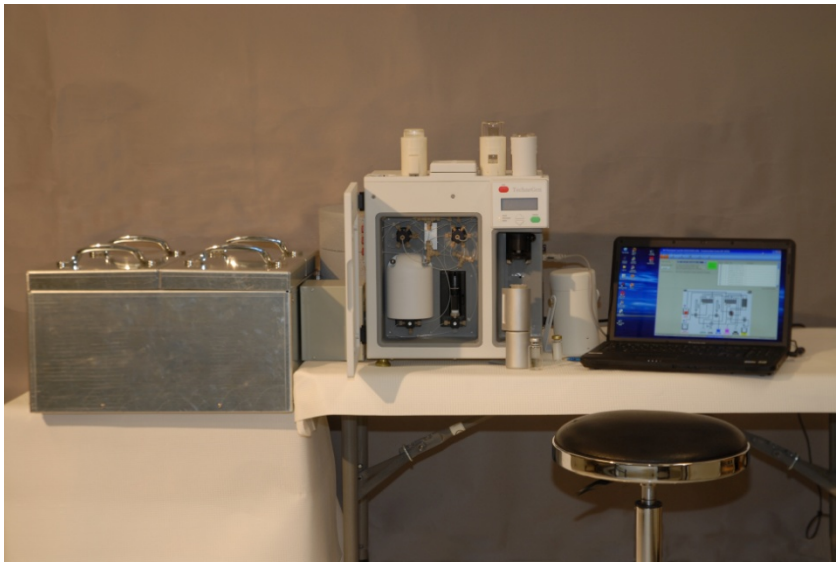
Process Byproducts & Waste

	Highly Enriched Uranium ("HEU") produced Mo99	Low Enriched Uranium ("LEU") produced Mo99	Mo99 Production Processes (2,3)
Uranium including U238, U235, U234	Yes	Yes	No
Plutonium-239	Yes	Yes	No
Fission products	Yes	Yes	No
Alpha emitting waste	Yes	Yes	No
Long-lived radioisotopes (1)	Yes	Yes	Yes

1. Includes long-lived technetium-99
2. The cost to dispose of NorthStar's waste is <1¢ per mCi of Technetium-99m.
3. NorthStar has the ability to recover its raw material for reuse, thus reducing the cost of its raw material and reducing the volume of material to be handled as waste.

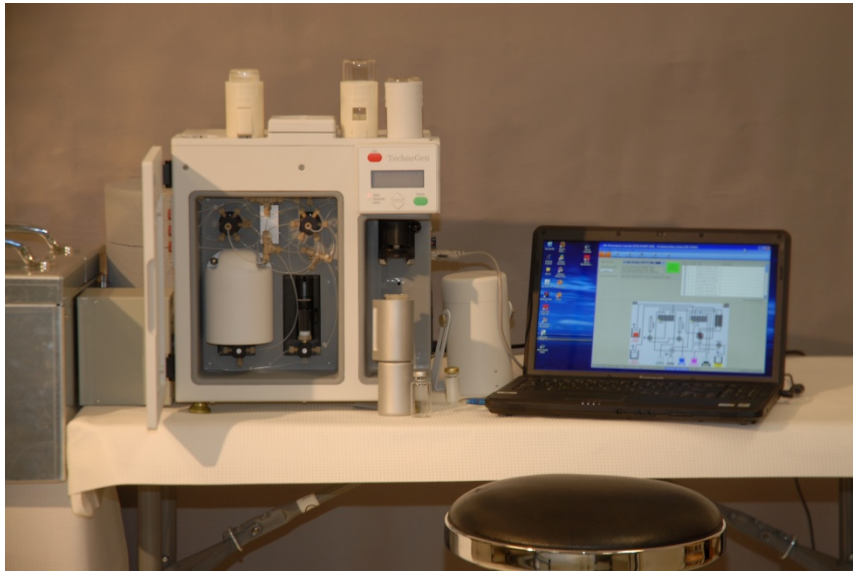
TechneGen™

TechneGen



- Single Control System for up to (4) Mo99 Isotope Sources (scalable & shielded),
- Chemistry for Tc99m production is unaffected by Mo99 production route: Natural Mo material, enriched Mo, neutron activated, photon activated, or fission (uranium),
- Single administrative computer capable of multiple TechneGen control
- Microprocessor controlled instrument which runs independently from the PC when processing begins,
- Local shielding for Mo99 sources,
- Complete database history logged for each Tc99m elution,
- Automated operation after prerequisites, and
- Separable PC to a laboratory area – dedicated TCP/IP network link.

TechneGen Instrument



- Localized shielding for Tc99m elution,
- Chemistry "kits" developed to control use of the instrument,
- User Interface optimized to reduce bioburden,
- Certified Protocols allow authorization for Tc99m elution
- Local display on instrument for progress review,
- Tc99m produced after passing thru a virgin Alumina Column, and redundant (2) sterility filters,
- Spent isotope source materials completely recyclable, and
- Ease of install, training and daily use – nuclear pharmacist assisted in design

- **FDA 505(b)(2) NDA application in process – received FDA comments on Monograph and Microbiology test plans – NorthStar proceeding with FDA guidance – NDA submission is in process**

TechneGen – development history
ARSII results at ANL and NRC-Canada

- *ARSII run 4 cycles, ~10 days each cycle, over a 3 month period at ANL beginning March 2010*
  - *Tc99m yields averaged >95% (industry avg. with current generators ranges from 70%-90%[1])*
  - *When pH in range (4.5-7.5; USP)*
    - *Al breakthrough <10ppm (<10ppm required)*
    - *Mo breakthrough <0.015µCi/mCi Tc99m (<0.15µCi/mCi required)*

- *ARSII installed at National Research Council of Canada in October 2009*
  - *Tc99m yields averaging >90%; purity 99% (>95% required)*
  - *When pH in range (4-8; Eu. Pharm.)*
    - *Al breakthrough <10ppm (<10ppm required)*
    - *Mo breakthrough <0.015µCi/mCi Tc99m (<0.15µCi/mCi required)*
  - *Sterile product (even <u>without</u> sterile input solutions and columns)*

1) *Radiopharmaceuticals in Nuclear Pharmacy and Nuclear Medicine*, 2nd Edition, by Richard J. Kowalsky and Steven W. Falen, published by the American Pharmacists Association, 2004, p. 218

TechneGen – development history
NRC-Canada

QC test	Criterion	^{99m}Tc tagged to tetrofosmin	^{99m}Tc tagged to MDP
Appearance	Clear, colourless	Pass	Pass
pH	5-9	6	6
Aluminum	< 10 ppm	Pass	Pass
Radiochemical purity	>95%	99%	99%
Radionuclidic purity	^{99}Mo/^{99m}Tc < 0.00015	Pass	Pass

QC Results for sodium pertechnetate produced at NRC

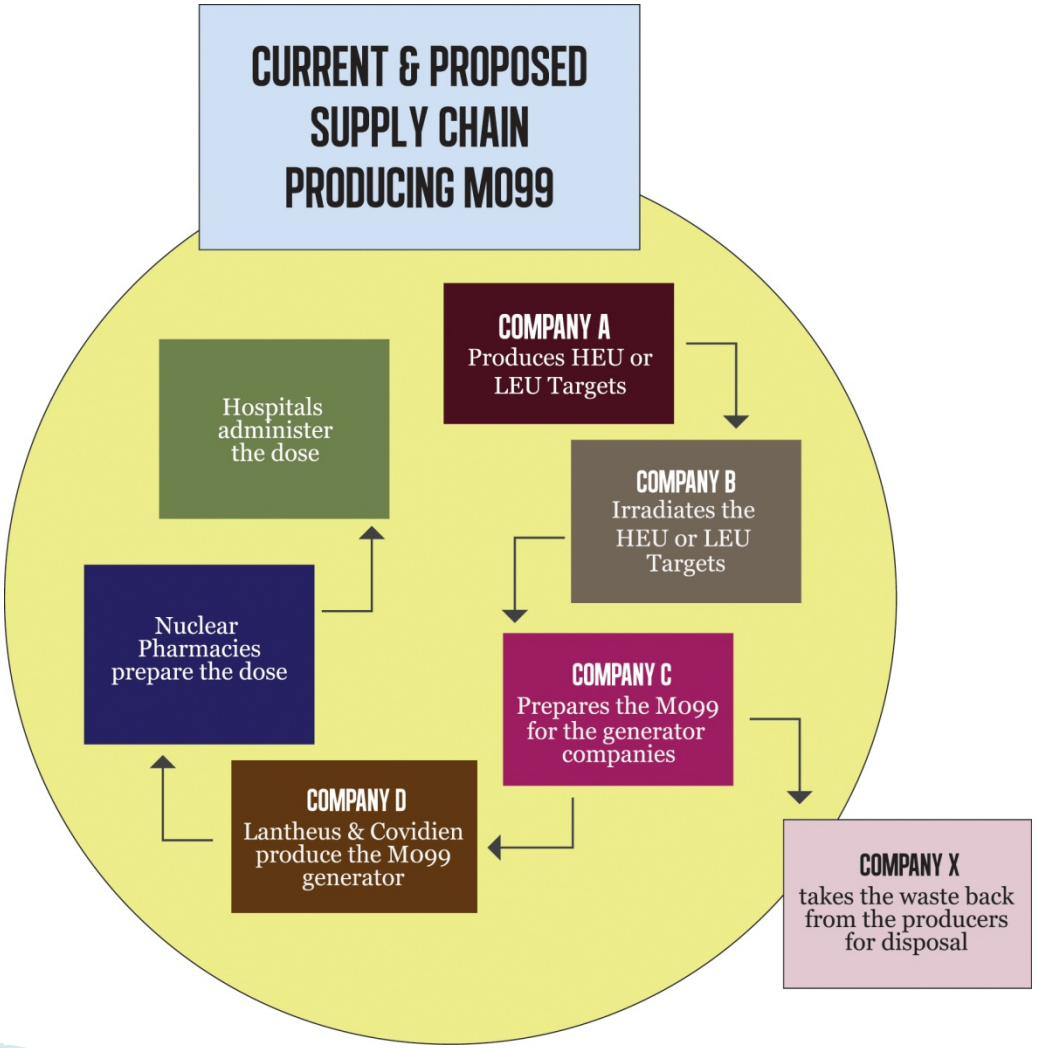
TechneGen – development history
NRC-Canada

QC test	Criterion	^{99m}Tc-tetrofosmin	^{99m}Tc-MDP
Appearance	Clear, colourless	Pass	Pass
pH	7.5-9 and 6.5-7.5	6	7
Radiochemical purity	>90%	98.3%	96.5%[1]
Radionuclidic purity	^{99}Mo/^{99m}Tc < 0.00015	Pass	Pass
Bacterial enodtoxins	<0.125 EU/mL	Pass	Pass
Sterility	Sterile	Sterile	Sterile

QC Results for tagged Myoview (tetrofosmin) and MDP produced at OHI

Supply Chain

Reactor Produced Mo99 Supply Chain & Other Proposed Supply Chain



NorthStar's Supply Chain

Summary

- Of all of the methods being proposed, no process has demonstrated technology viability as well as NorthStar has.
  - NorthStar has produced Mo99 from both production methods and has demonstrated that it's Mo99 meets the European monograph for Mo99,
  - NorthStar's TechneGen™ technology has consistently produced Tc99m with yields and purity levels drastically improved over current generators and has demonstrated that the Tc99m meets the USP monograph.
- Both (n,γ) and (γ,n) Mo99 production processes by NorthStar use stable molybdenum isotopes as target material.
  - With (γ,n) or (n, γ) Moly, the target material is recoverable thus reducing the cost of the Mo100 or Mo98.
  - Both production methods present a more reliable supply
  - MURR's reactor up time performance cannot be matched by any reactor at least in the US
  - NorthStar's (γ,n) LINAC Moly produced is completely redundant where down time will be transparent to the customer.
  - NorthStar performs most steps in the supply chain – one corporate overhead, G&A and profit

These factors offer NorthStar a powerful competitive advantage.

Discussion