Santa Fe Paper -AHR

Production and Purification of Molybdenum-99 using Low Enriched Uranium and Low Cost Swimming Pool Reactor and Underwater Transfer Techniques

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BACKROUND

- 1.1 Conception in 1992, Patented (assigned to B&W) in 1994.
- 1.2 Papers presented at RERTR, IAEA, and Society for Nuclear Medicine conferences, ANS Transaction publication

MIPR Description and operational sequence

- 2.1 Assembled and tested prior to insertion in deep swimming pool (8 meters) Low cost real estate
- 2.2 Pool water cooled to 5 C with chiller system
- 2.3 200 liters of uranyl nitrate (or sulfate) in dump tanks, concentration is 100 grams of low enriched uranium per liter. Prior to each campaign, instrumentation and scram system tested with gamma source on pole

- 2.4 200 straight cooling tubes, zircaloy, in 2 meter high zircaloy tank, 60 cm ID (no graphite reflector, easy in situ inspection of tubes) Tube placement for power flattening (Kochendarfer paper)
- 2.5 Safety rods move up, above solution, dump valve closed, air pressure moves solution into the core tank, criticality at 1 meter high. 1 meter portion above solution is for “chimney effect” to enhance convection.
- 2.6 Power raised to 200 kW. Solution at 80 C is passively and convectively cooled by pool water moving through straight tubes. System runs from 1 to 5 days (7000 curies)
- 2.7 Vapor and droplets trapped on mesh above solution and fall back into core. Non-condensable radiolytic gases recombined with catalytic converter in space above tank
- 2.8 Reactor shutdown with safety rods and allowed to cool in core tank for about 1 hour (1% of operating power, 6 hours 0.5%)
- 2.9 Staubli valves direct fluid through extraction columns (TiO or alumina) – 4 hours estimate flow by gravity – solution returns to dump tank

- 2.10 Valving directs NaOH solution to elute Moly on columns and transfers it to purification pool
- 2.11 Purification pool has dowex and charcoal columns (proven technique used by IRE for decades) and elutriant flows through by gravity to final collection
- 2.12 Cows are loaded in shielded box and QA performed before shipments Net production is about 1000 six-day curies per week

Supporting test work completed
(All work internally supported)

- 3.1 Full length convective cooling tests at nCore – ANS Paper in June 2011 – heat removal 1 kW per cooling tube
- 3.2 Corrosion tests of zircaloy in uranyl salt including crevice test – 80 C, 1000 hours – no weight losses or evidence of pitting
- 3.3 Catalytic converter tests with commercial converter

Planned work
(with external support)

- 4.1 Corrosion tests of zircaloy in fissioning solution
- 4.2 Tests of extraction efficiency and purity of solution with fission products
- 4.3 Mockup of hydraulics and valving (non-nuclear) PIC OF DEEP TANKs

Economics and Conclusion

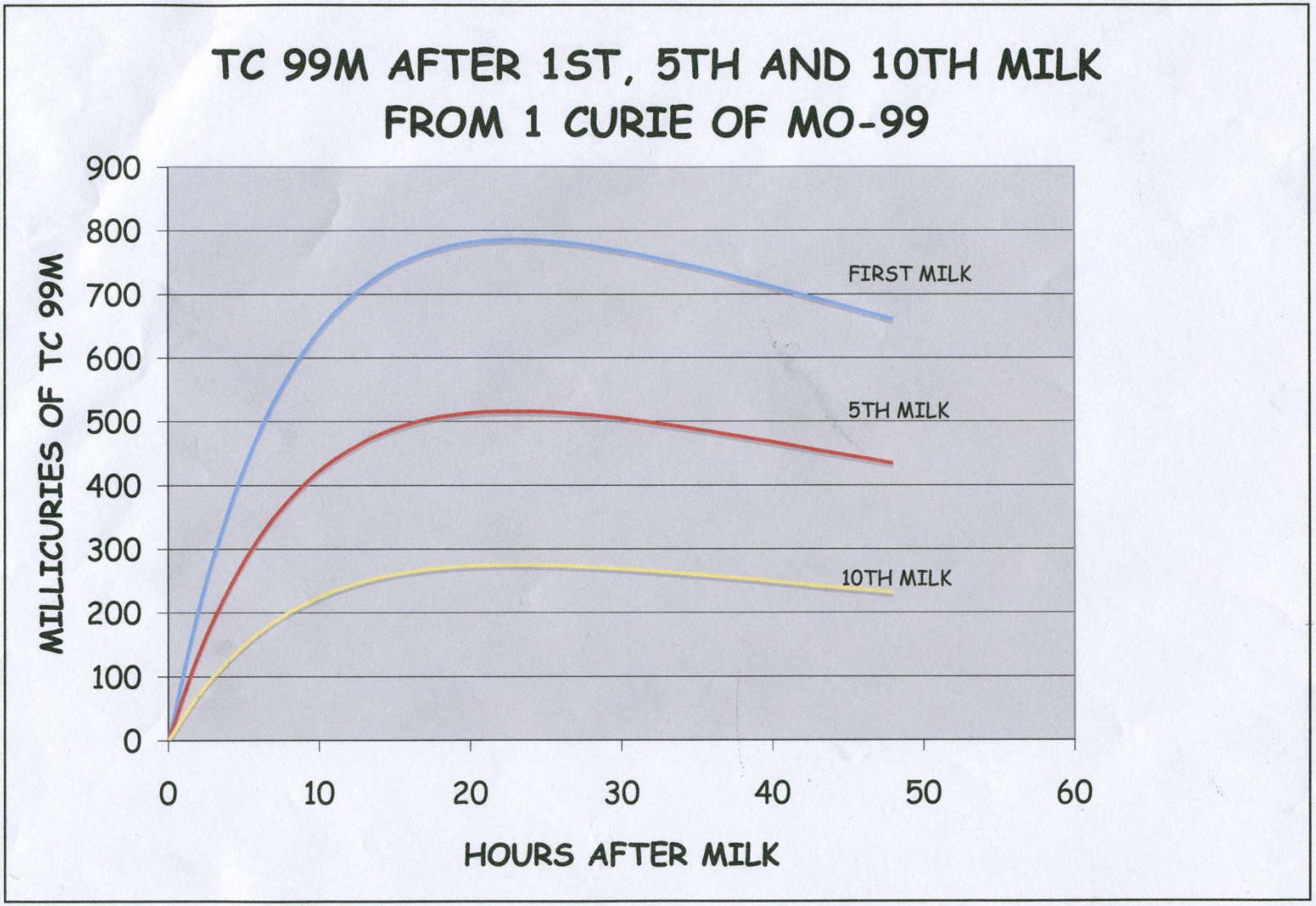
- 5.1 OECD Reports provide marketing data
- 5.2 Social contract (Gov subsidy) causing market failure
- 5.3 Using only marginal costing - $75/six-day curie to cow makers (Lantheus and Covidien)
- 5.4 Our estimates: Capital cost to create facility = $30 million includes purification system
- 5.5 Operating costs include finance charge, waste disposal, depreciation and decommissioning lead to cow price of $300 per six-day curie, increment to patient, about 3%
- 5.6 All competing proposals should provide similar details

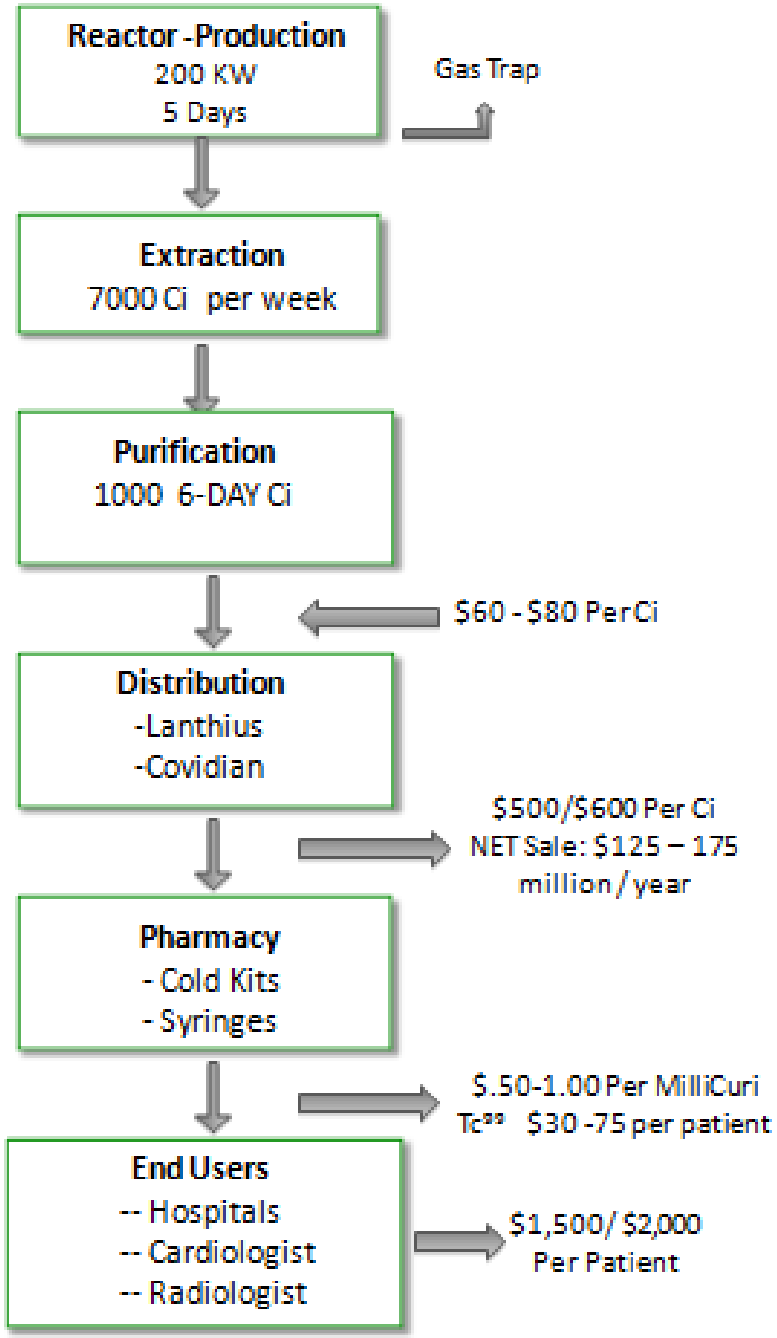
Why Mo^{99} production in the US is currently uneconomical

- Government sponsored reactors, both in Canada and Europe, process and sell Mo^{99} only at the marginal cost of production with no capitol recovery (~$75 per Ci)
- A low cost 200+ KW dedicated Aqueous homogenous reactor, capitalized at $30 million, can breakeven at ~ $250 per Ci. Other systems are likely higher.
- Current isotope cost for patient cardiac imaging sestamibi injectable is less than $100, where the entire procedure cost is ~ $2000.
- Increasing raw Mo^{99} cost from $75 to $300 per Ci at the distribution level (i.e. Covidian/Lanthius) will drive the isotope pharmacy cost from $625 to $800 per Ci, and net sestamibi cost from $100 to $160 (an increase of $60 per patient).
- Medicare recently reduced the reimbursement to clinicians to $1500 per procedure which will restrict access to perfusion studies.

Background

- The two major Mo^{99} distributors in the US sell approximately $2.5 million per week ($125M - $150M per year) to nuclear pharmacies.
- Nuclear pharmacies resell Tc^{99} for $500 to $1000 per Ci where one Ci of Mo^{99} yields approximately five Ci of Tc^{99}.
- ***Obtained from OECD documents; interviews with nuclear pharmacies and cardiologists; Covidien & Lanthius 10k documents.




Reactor -Production
200 KW
5 Days
Gas Trap
Extraction
7000 Ci per week
Purification
1000 6-DAY Ci
$60 - $80 Per Ci
Distribution
-Lanthius
-Covidian
$500/$600 Per Ci
NET Sale: $125 – 175
million / year
Pharmacy
- Cold Kits
- Syringes
$.50-1.00 Per MilliCuri
Tc⁹⁹ $30 -75 per patient
End Users
-- Hospitals
-- Cardiologist
-- Radiologist
$1,500/ $2,000
Per Patient

Available Experimental Pool in Forest, VA – 8M Dia x 8m Deep

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