Reactor Physics Calculations for ^{99}Mo Production at the Annular Core Research Reactor*

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Introduction

The Isotope Production and Distribution Program at the Department of Energy has designated Sandia National Laboratories as the "most appropriate facility" for the production of ^{99}Mo, a radioisotope whose daughter, ^{99m}Tc, is used in over 36,000 medical procedures per day in the U.S., and considered to be a vital medical diagnostic and treatment tool.[1] The isotope would be produced at Sandia using the Annular Core Research Reactor (ACRR) Facility and collocated Hot Cell Facility. The ^{99}Mo would be produced using the fission process by irradiating "targets" coated with ^{235}U in the form of highly enriched U_3O_8. After approximately seven days of continuous irradiation in the (ACRR), a target would be removed from the reactor core for processing. The isotope would be extracted by chemically precipitating the molybdenum using the "Cintichem" process,[2] and would be shipped to the various pharmaceutical companies by commercial or chartered airline.

ACRR Description

The ACRR is a research reactor designed to operate in a pulse or steady-state mode.[2] It consists of an array of 236 UO_2-BeO fueled elements clad with stainless steel. The reactor is submerged in an open pool ~10 m deep. A dry irradiation cavity ~22.5 cm in diameter occupies the center region of the core and extends to the surface of the pool. The core is cooled by natural convection. The core has been operated to 4.5 MW in the steady-state mode, corresponding to a peak fuel element power of 26 kW. For ^{99}Mo production the dry central cavity will be removed from the core, allowing for a large flux trap area where targets can be placed for irradiation.

The amount of ^{99}Mo that can be produced is a function of the fission power produced in each target, the number of targets irradiated, and the irradiation time. Assuming that the U.S. demand requirements for ^{99}Mo is 16,500 Ci per week at the source, the total fission power required in the targets can be calculated to be about 400 kW, assuming that each target is irradiated for 7 days.

Analysis Description

The Monte Carlo neutronics computer code, MCNP[3], was used extensively in determining the optimum configuration for production. A three dimensional core

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geometry was modeled, with every fuel element and control element identified individually. One to 37 targets were analyzed in the flux trap region, and the core size varied from 123 to 236 fuel elements. A cross-sectional view of the ACRR core model with the central cavity in place and core modified to accept 19 targets is shown in Figure 1. A smaller core is required with targets placed in the flux trap region because of the positive reactivity effects of the targets.

Results and Conclusions

Table I shows the results of the analysis for various fractions of the U.S. demand. The peak fuel element power in the core was arbitrarily chosen as 26 kW and the irradiation time per target was seven days. The calculations used room temperature cross sections. For each case shown, an excess $6.50 of reactivity was required to compensate for temperature and xenon effects. All cases used a water radial reflector, except for the case of 37 targets, where a nickel reflector was added to reduce the excess reactivity of the core.

The results indicate that, although the ACRR operates at a relatively low power level, the U.S. demand for ^{99}Mo can be easily met using a reasonable number of targets. Demand greater than that of the U.S. can also be achieved; irradiation of 37 targets would allow for up to 140% of the market to be met. Target design and other configuration changes will allow for even greater production levels to be achieved.

References

1. "Late News in Brief," *Nuclear News*, **37**, 17 (Nov. 1994).

2. R. L. COATS, E. J. PARMA, "Medical Isotope Production: A New Research Initiative for the Annular Core Research Reactor," *Proc. Topl. Mtg. Advances in Reactor Physics*, Knoxville, Tennessee, April 11-15, 1994, Vol. III, p. 60, American Nuclear Society.

3. J. F. BRIESMEISTER, Ed., "MCNP - A General Monte Carlo N-Particle Transport Code, Version 4A," LA-12625-M, Los Alamos National Lab. (Nov. 1993).

Table I
Target/Core Configurations for Various U.S. Demands

Fraction of U.S. Demand	Required Power Level From Targets (kW)	Number of Targets	Number of Fuel Elements Required	Total Core and Target Power (MW)
0.37	148	7	181	3.14
0.68	272	13	165	3.03
1.00	400	19	148	2.91
1.40	560	37	129	2.66

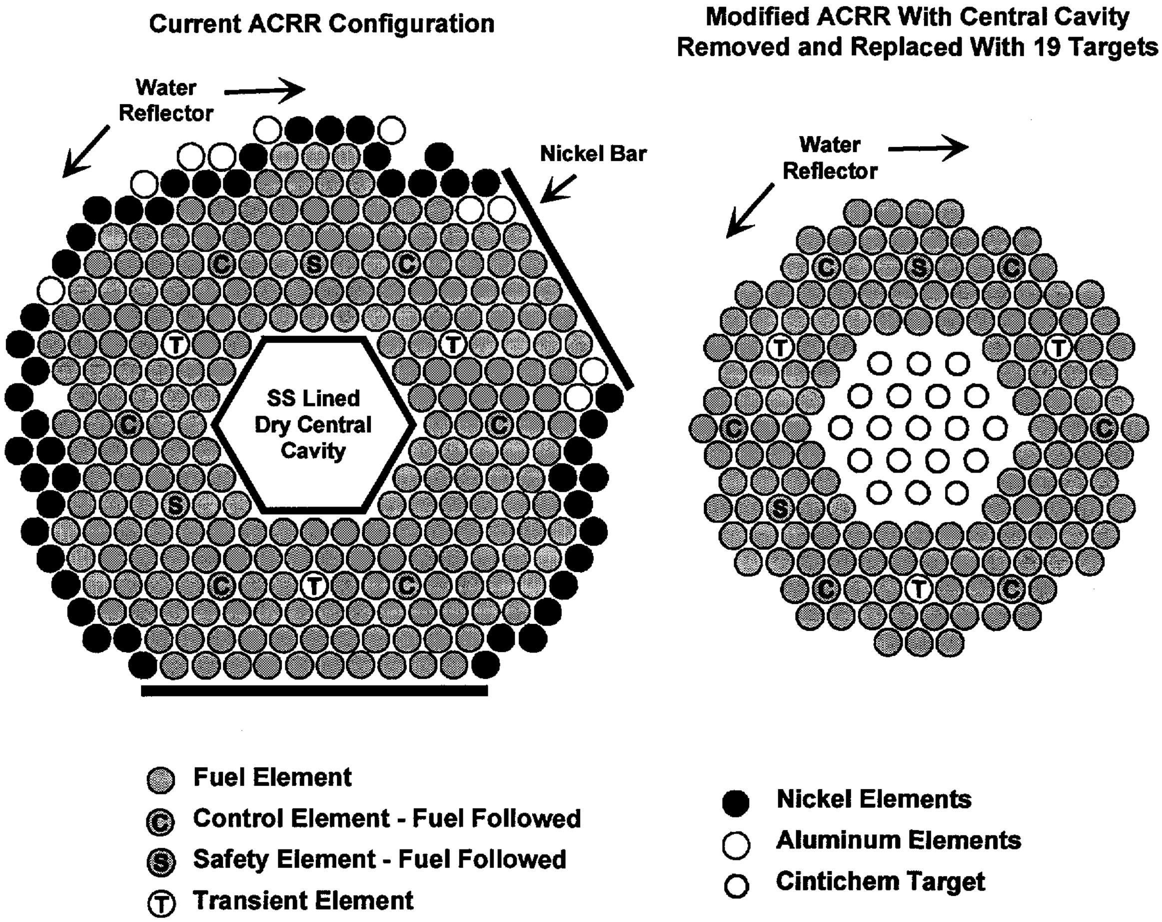

Fig. 1. Cross-sectional view of the ACRR core.