MO-99 PRODUCTION ON A LEU SOLUTION REACTOR

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ABSTRACT

A pilot homogenous reactor utilizing LEU has been developed by the Kurchatov Institute in Moscow along with their commercial partner TCI Medical. This solution reactor operates at levels up to 50 kilowatts and has successfully produced high quality Mo-99 and Sr-89. Radiochemical extraction of medical radionuclides from the reactor solution is performed by passing the solution across a series of inorganic sorbents. This reactor has commercial potential for medical radionuclide production using LEU UO_2SO_4 fuel. Additional development work is needed to optimize multiple 50 kilowatt cores while at the same time, optimizing production efficiency and capital expenditure.

1. Introduction

TCI Medical has been working with The Kurchatov Institute in Moscow and Argonne National Lab in Chicago, Illinois on the development of a LEU solution reactor for the production of Mo-99 and other medical radionuclides. A pilot solution reactor has been running successfully in Moscow since 1981, producing small quantities of Mo-99 from HEU UO_2SO_4 fuel.

Development work for this project has been funded by the *Initiatives for Proliferation Prevention* and the *Civilian Research and Development Fund.* To-date a great deal of development work has been completed. Samples of Mo-99 have been produced and compared to commercially available Mo-99 sources. The Mo-99 from the solution reactor met or exceeded all of the specifications of the commercial suppliers. However, detailed financial analysis has shown that the production quantities of sellable Mo-99 available from a single core 50 kW solution reactor cannot financially justify the capital expenditure.

Further development work needs to be done with a multiple-core design that will significantly increase Mo-99 output, with only a modest increase in capital cost. Further funding is needed to continue this work at The Kurchatov Institute. The proposed project would include converting the aqueous fuel from HEU to LEU and using it as a demonstration project for the production of medical radionuclides.

2. Discussion

The current process involves the fission of U-235 in the HEU aqueous solution of the reactor core. Many useful medical radionuclides are produced in the core, along with many other byproducts. At the completion of an operating cycle, the reactor solution is pumped through a series of inorganic

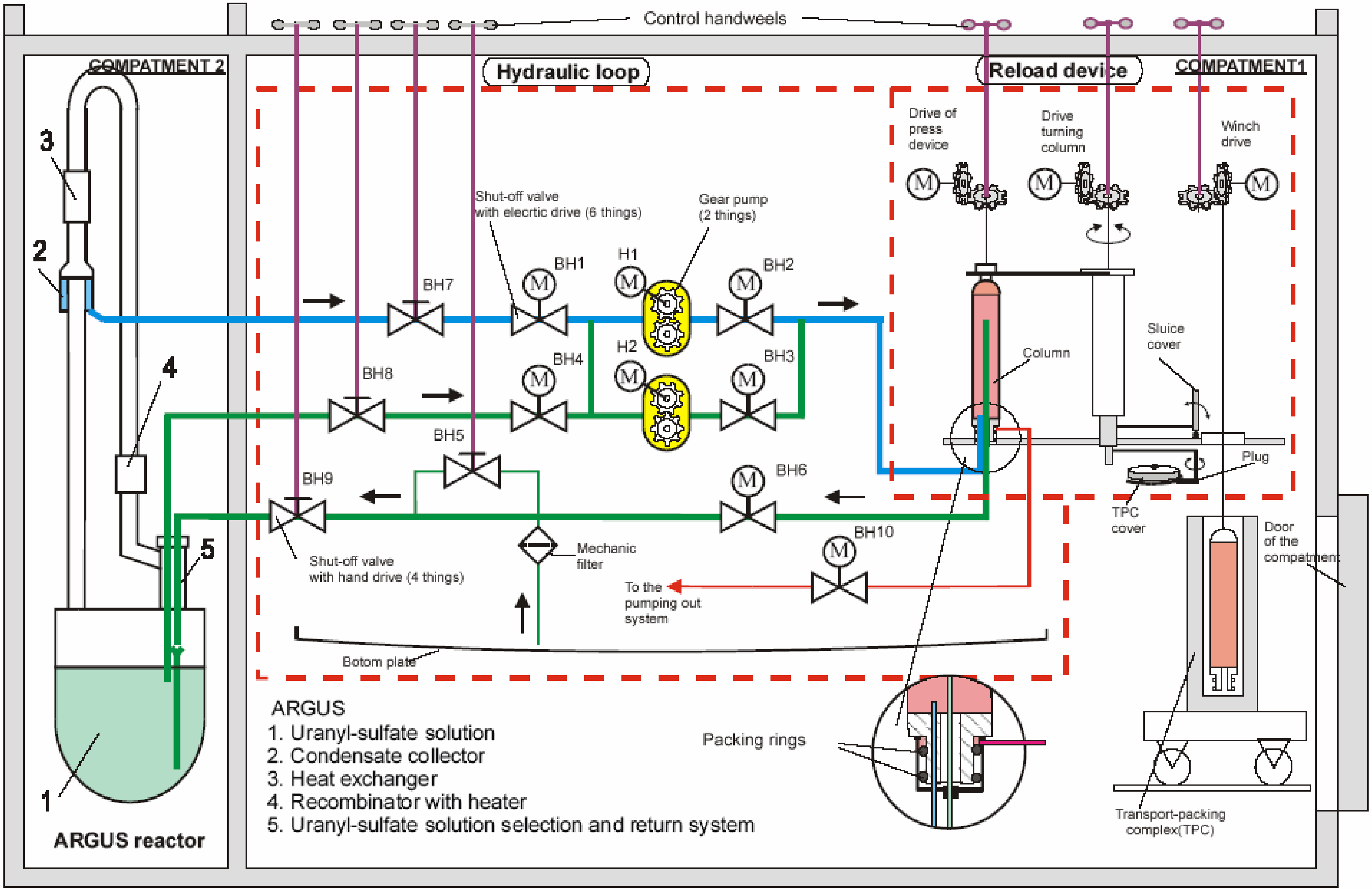

Figure 1. Schematic Layout of Solution Reactor and Radiochemistry Process

sorbent beds, which can selectively remove specific radionuclides of interest. This continuous loop pumps the reactor aqueous fuel is back into the reactor core at the completion of the absorption process. The resin beds and the captured radionuclides are then processed through additional sorbent columns for purification of the specific radionuclide of interest. A schematic of this system is shown on Figure 1.

The aqueous fuel in the proposed pilot reactor is Uranyl Sulfate (UO_2SO_4). The level of U-235 enrichment is <20%. The concentration of uranium in solution is 380 g/L, with a total core volume of 24 liters. All development work on this reactor and radionuclide production system has been based on these parameters. LEU fuel is seen as a valuable alternative to current commercial production efforts utilizing HEU.

The current solution reactor being operated at The Kurchatov Institute is running at a power level of 20 kW with HEU fuel. The current design can safely be increased to a power level of 50 kW. At this level the reactor can produce 250 (6-day) Ci per week. The reactor now relies on passive cooling through means of convection. If the powered level were to be increased an aggressive cooling system would need to be developed to dissipate the heat that is generated. Redundant cooling systems would also be required. For these reasons 50 kW is considered the upper power limit for this design. It is felt that LEU fuel will be capable of producing significant quantities of Mo-99 and other medical radionuclides.

TCI Medical has examined the cost to license and build a solution reactor for the production of Mo-99 in North America. These costs are significantly less than a conventional research reactor. However, when the power level is limited to 50 kW, the resulting production rate is 250 (6-day) Ci/wk. The revenue that is generated by the sales of this quantity of Mo-99 does not support the investment to build such a reactor. TCI Medical has turned its attention to increasing the output of such a facility, not by increasing the power level of a single core, but instead by designing a reactor system with multiple 50 kW cores using LEU fuel. The production of Mo-99 and other radionuclides goes up proportionally to the number of cores. The capital cost of building multiple cores does not increase proportionally. Consequently it is possible to build a reactor system with multiple cores in which you get an acceptable financial payback to justify the capital expenditure. This is the current and future area of concentration on this project.

In order to produce Mo-99 and other medical radionuclides that are used to manufacture radiopharmaceuticals, the drug regulatory authority requires a detailed production process, called a *Drug Master File* (DMF). The DMF helps to assure that the drug substance (Mo-99) is produced consistently and to exacting specifications. A DMF has already been produced for the Mo-99 process on the solution reactor at The Kurchatov Institute.

3. Future Direction

The future direction for this project is focused on developing a multiple core concept and LEU fuel. The single core 50 kW design does not justify the financial investment. The use of multiple 50 kW cores increases the production and sales of Mo-99 and other radionuclides to a level that would justify the capital expenditure. Output of Mo-99 is proportional to the total power level of multiple cores. Output for Mo-99 is stated in units of *6-day* Ci. By industry convention, this indicates the level of Mo-99 produced at a time of six days prior to the calibration date. This is in reference to the calibration date of the Tc-99m generators for which the Mo-99 is used. The output for the multiple core configurations is estimated below:

2 x 50 kW cores	500 (6-day) Ci per week
4 x 50 kW cores	1000 (6-day) Ci per week
6 x 50 kW cores	1500 (6-day) Ci per week
8 x 50 kW cores	2000 (6-day) Ci per week
10 x 50 kW cores	2500 (6-day) Ci per week

The cost to produce the considering the capital investment and operating costs is closely tied to the total power level, the number of 50 kW cores, and consequently the sales that can be generated for the radionuclides produced. The financial model developed shows a steady decrease in production cost as a function of total number of cores. This can be seen graphically in Figure 2. This is further demonstration that the multiple core concept provides the best payback for the capital money invested.

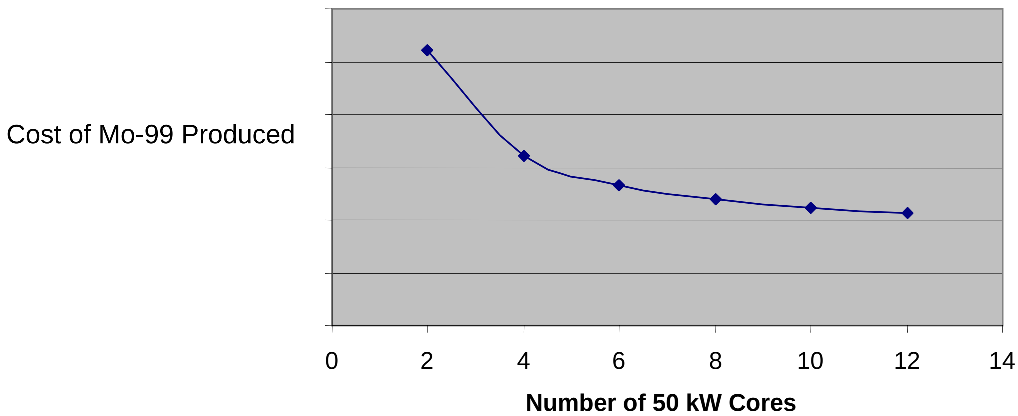

Figure 2. Cost of Mo-99 Produced vs. Number of Cores

4. Conclusions

Further development work needs to be done on this multiple core concept. The financial model makes a compelling case of the business viability of this reactor system. If the continued development work validates the work done to-date, than this LEU reactor will be able to produce Mo-99 and other medical radionuclides while returning an acceptable level of return on the money invested.

TCI is proposing additional funding of this project at The Kurchatov Institute in Moscow so this work can be continued. The immediate proposal is to convert the existing HEU reactor to LEU and use it as a pilot facility for the production of medical radionuclides. This solution reactor continues to hold promise both philosophically and as a viable business alternative.