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Comments on Alexander Dmitriev's Paper Entitled "Conversion of the Russian Plutonium Production Reactors: Transition to the Second Phase"

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This paper provides an appropriate update of the history, evolution, and status of the Core Conversion Project for the Russian Plutonium Production Reactors since Alexander Dmitriev's 1994 paper.[1] During that time, the Russian Federation has decided to include these production reactors under the nuclear regulatory approval authority of Gosatomnadzor (GAN) for the design, plant modification, fuel fabrication, and reactor operations related to core conversion. GAN will provide civilian nuclear safety oversight for the production reactors, which are currently owned and controlled by the Ministry of Atomic Energy (MINATOM). As Deputy Chairman of the GAN organization responsible for review and certification of the core conversion design being conducted by the MINATOM team (led by the Kurchatov Institute), Alexander Dmitriev is developing the nuclear safety regulatory requirements for core conversion. His paper provides potential insights into the aspects of the core conversion design that Dmitriev has identified as important.

The fuel loading scheme described by Dmitriev was developed at the Siberian Chemical Plant in 1992 where two of the three operating production reactors are located. Prior to being appointed to his current position at GAN, Dmitriev was responsible for production reactor engineering and operations at the Siberian Chemical Plant, including the feasibility study for the annular fuel with internal absorber loading scheme. His experience at the production reactors provided him with insight and a keen interest in progress of the core conversion process. When the joint Russian/American feasibility study of technical options for core conversion was completed at the end of 1995, the alternating cylindrical fuel and absorber element channel loading scheme was selected as the reference design concept. The design features of the fuel load-

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ing scheme being developed for MINATOM that uses alternating cylindrical fuel and absorber elements in the channels were not discussed in Dmitriev's paper because the design documents have not yet been submitted to GAN for review.

The examples cited by Dmitriev, for the fuel loading scheme that he has analyzed, illustrate the difficulty of satisfying more stringent nuclear safety requirements intended for new commercial reactors, when backfitting system and fuel modifications to reactors currently in operations. In 1998, MINATOM will submit a Final Safety Analysis Report (FSAR), including a Probabilistic Risk Assessment (PRA), on core conversion to GAN for review and approval. The modifications to plant systems will not begin until GAN certification of the design and FSAR for core conversion is obtained.

The paper by Dmitriev is somewhat unusual, in the context of his current position at GAN, because it raises technical issues regarding the MINATOM team's design before the details of the design and supporting analyses are submitted for GAN review.

The article points out two technical constraints for the core conversion. The first being the correct prediction of the reactors' behavior and the second being safety requirements surrounding reactivity and power distribution. The institutional and economic constraints on the core conversion must also be met for the successful completion of the project. Since these reactors were commissioned in the early 1960s, they are approaching the last 10 to 12 years of useful life. If the process of core conversion cannot be accomplished in the relatively near future, around the year 2000, the cost effectiveness of conversion is in doubt. Dmitriev points out that design and safety analysis would take 1.5–2.0 years and the complete cycle of fuel testing and certifications would require 3–4 years. He correctly concludes that an existing fuel design must be used in the converted core to meet the schedule.

The only two fuel designs with production reactor experience, making them candidates for core conversion, are both uranium oxide in an aluminum matrix with aluminum cladding. One has cylindrical geometry and the other has the annular geometry.

Even though annular fuel is not used in the operating reactors, the author prefers this design because it has the potential for compensating for fission product poison buildup and manipulating reactor power/reactivity distribution. Neutron flux distribution in the reactor core can be manually manipulated when boron steel is inserted or removed from the fuel annulus.

Even with the combination of boron and gadolinium used as absorbers in the converted core, calculations at PNNL show the changes in reactivity during a two year batch core lifetime exceed the capabilities of the existing control rod system. This indicates the manual manipulation of additional absorbers, as the author suggests, is necessary. In addition, such manipulations are subject to absorber unloading mistakes as the author points out in criticism of the reference design concept.

The fundamental difficulty is imposed by the desire to operate the reactor core in the "batch mode." The batch mode is a characteristic mode of Russian reactor operation where the core is loaded with fresh fuel and operated for up to two years without replacing any of the fuel. The difficulty arises because the fuel and absorbers are burned out at different rates. Reactivity variations cause all of the problems the author recites; lack of shutdown margin, poor power distribution, large reactivity variations from cold to hot conditions, etc.

Based on the current mode of operation at the Russian production reactors, as well as international experience with other graphite moderated reactors and commercial light water reactors, the simplest solution is to replace a fraction of the fuel on a regular schedule. As an example, one third of the reactor fuel could be replaced every eight months. Burnup of fuel could be optimized to enhance the economy of reactor operation. Combined with burnable absorber selection, core reactivity could be maintained nearly constant. Narrowing the range of reactivity variations would also increase the safety of reactor operation while maintaining a negative coolant void coefficient of reactivity.

Preliminary PNNL calculational estimates indicate that it would be possible to keep reactivity variations to 3 percent over an eight month period. With the scram system worth 9 percent, fission poisons worth 3 percent and reactivity changes from cold to hot of 2.5 percent, the shutdown margin would be maintained above 3.5 percent at all times without making manual manipulations suggested by the author.

In conclusion, all of the issues raised by Dmitriev associated with reactivity are valid and will challenge the MINATOM design team to meet GAN requirements for reactor operation and safety. The author has suggested extraordinary means to compensate for large reactivity variations by suggesting a fuel design and operations that would be new to these reactors. If relief can be obtained from the design constraint for a batch mode of operation and core loading, a scheme of periodic discharge and reloading of fuel in a portion of the core can meet the economic, technical and safety requirements while using proven fuel for core conversion in these reactors.

NOTES AND REFERENCES

1. Dmitriev, A.M., "Converting Russian Plutonium-Production Reactors to Civilian Use," *Science & Global Security*, Vol. 5, (1994), pp. 37–46.