THE GAS TURBINE-MODULAR HELIUM REACTOR FOR THE NEXT FIFTY YEARS OF NUCLEAR POWER

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ABSTRACT

The Gas Turbine-Modular Helium Reactor (GT-MHR) is the result of coupling the evolution of a low power density passively safe modular reactor with key technology developments in the U.S. during the last decade: large industrial gas turbines; large active magnetic bearings; and compact, highly effective plate-fin heat exchangers. This is accomplished through the unique use of the Brayton cycle to produce electricity with the helium as primary coolant from the reactor directly driving the gas turbine electrical generator. This cycle can achieve a high net efficiency in the range of 45% to 48%.

In the design of the GT-MHR the desirable inherent characteristics of the inert helium coolant, graphite core, and the coated fuel particles are supplemented with specific design features such as passive heat removal to achieve the safety objective of not disturbing the normal day-to-day activities of the public even for beyond design basis rare accidents.

Each GT-MHR plant consists of four modules. The GT-MHR module components are contained within steel pressure vessels: a reactor vessel, a power conversion vessel, and a connecting cross vessel. All vessels are sited underground in a concrete silo, which serves as an independent vented low pressure containment structure.

By capitalizing on industrial and aerospace gas turbine development, highly effective heat exchanger designs, and inherent gas cooled reactor temperature characteristics, the passively safe GT-MHR provides a sound technical, monetary, and environmental basis for new nuclear power generating capacity.

This paper provides an update on the status of the design, which has been under development on the US-DOE program since February 1993. An assessment of plant performance and safety is also included.

INTRODUCTION

The challenge for the nuclear industry in the 1990s will be the development of plants that address matters of public acceptance, improved safety, competitive generating costs and reduced radioactive waste. The GT-MHR which has evolved from the steam cycle Modular High Temperature Gas Cooled Reactor (MHTGR) firmly addresses each of these issues.
Like the MHTGR, the GT-MHR relies on design selections and passive safety systems to assure retention of radionuclides within the TRISO coated fuel particles. Utilizing a special annular core design which is larger and located nearer to the reactor vessel and Reactor Cavity Cooling System than the MHTGR, peak fuel temperatures during a rare loss of forced cooling and pressure event are within the design goal for the fuel of 1600°C.

The GT-MHR is an environmentally acceptable power plant that has a high degree of inherent safety characteristics. These inherent safety characteristics coupled with a direct cycle gas turbine allow design simplifications that help control costs and schedule. The GT-MHR can uniquely use the Brayton cycle to produce electricity by directly driving a gas turbine electrical generator. The GT-MHR can achieve a net efficiency in the range of 45% to 48%. This high efficiency leads to competitive economics when compared to the 32% net efficiencies achieved by advanced water cooled reactor power plants. High thermal efficiencies lead to an environmentally compatible design that produces about 50% less high level radioactive waste and about 100% less thermal discharge to the environment than comparably sized LWRs (Ref. 1).

The GT-MHR evolved from a 10 year design effort on the steam cycle MHTGR funded under the U.S. DOE Advanced Reactor Program. Producing ~286 MW(e) per reactor module, the GT-MHR retains many of the key MHTGR design features including refractory coated TRISO fuel, low power density core, factory fabricated steel vessels, below grade siting, and completely passive decay heat removal. Most importantly the GT-MHR retains the capability of meeting all safety goals without relying on active safety systems or operator actions. The GT-MHR couples this impressive safety performance to several key technology developments of the last decade: large industrial gas turbines, large active magnetic bearings, and compact plate-fin heat exchangers. The major difference from the steam cycle design is instead of using steam to drive a steam turbine plant at 38% of efficiency, the GT-MHR produces electricity directly in a closed-cycle helium turbomachine at 45% to 48% net efficiency, thereby eliminating the expense and complication of the steam plant equipment.

The GT-MHR addresses the issues of the 1990s by providing a step increase in economic performance combined with reduced environmental impact and increased reactor safety.

**GT-MHR PLANT DESIGN**

In the design of the GT-MHR the desirable inherent characteristics of the inert helium coolant, graphite core, and the coated fuel particles are supplemented with specific design features to ensure passive safety. Radionuclides are essentially retained under all licensing basis events within the refractory coated fuel particles. The integrity of the particle coatings as a barrier is maintained by limiting heat generation, assuring means of heat removal, and by limiting the potential effect of air and water ingress under potential accident conditions. The design of the GT-MHR provides redundant and diverse active systems to perform these functions for both normal and transient conditions. However, consistent with the safety and performance objectives, the fuel integrity is maintained because of inherent MHR characteristics and passive design features without the need for active AC powered systems or operator action.

The key features and design selections to ensure the GT-MHR’s safety goals include:

- **Helium Coolant** - The inert and single-phase helium coolant has several advantages.

  No flashing or boiling of coolant is possible, pressure measurements are certain, no coolant level measurements are required, and pump cavitation cannot occur. Further,