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GAS COOLED FAST REACTOR FOR GENERATION IV SERVICE

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ABSTRACT

The Gas Cooled Fast Reactor (GFR), which is among the Generation IV concepts under evaluation for future deployment, will have to satisfy the Gen IV goals in the area of sustainability, safety and economy. This paper discusses challenges posed by the GFR when striving for the achievement of balance among the above Generation IV goals, and the pros and cons of various design choices. Considering these goals, the currently preferred design direction at MIT is a GFR design using a direct supercritical CO_2 cycle, traditional containment with design pressure of 5 bars, employment of redundant active emergency cooling systems with highly reliable and diverse power supplies, which can also function in the passive mode as a backup at 5 bars containment pressure, and TRU fueled cores using either block-type (TRU-U)C fuel or pin type (TRU-U)C fuel with double cladding or (TRU-U)O_2 fuel vibropacked in a tube-in-duct assembly.

KEYWORDS

Gas cooled fast reactor; Coolant void reactivity; Decay heat removal; Safety;

1. INTRODUCTION

Recently, gas cooled thermal reactors coupled to a direct Brayton cycle, such as the MHR-GT (Shenoy *et al.*, 2003), the ESKOM direct cycle 115 MWe Pebble Bed Modular Reactor (PBMR) currently in the licensing process in South Africa, and scheduled for construction in the near future (Gittus, 1999) and GTHTR300 (Yan *et. al.*, 2003) have gained prominence and are considered as promising candidates for future plants for both electricity generation and hydrogen production due to their robust safety, high efficiency and potential to operate at the high temperatures needed for thermochemical processes for hydrogen production. These thermal reactors operate in a once-through cycle and their particle fuel allows a significant increase in discharge burnup and thus reduced waste generation per unit of produced energy in comparison with LWRs. However, in the long term if nuclear energy expands to the hydrogen production and transportation sector, large deployment of these reactors will ultimately necessitate adaptation of a closed cycle to minimize waste production and efficiently utilize uranium resources. This need is also highlighted in Generation IV goals for future plants (Levy *et al.*, 2001), which among others require long-term sustainability, in terms of resource utilization, waste minimization and proliferation resistance. Therefore, a fast gas cooled reactor, which can address the sustainability issue and achieve high uranium utilization and recycling of actinides and at the same time benefit from the high efficiency typical of gas cooled reactors is of considerable interest.

Gas cooled fast reactors have been explored in the past (Gratton, 1981; Kemmish, 1982). Almost all early studies involved indirect cycle-reactors with a classical Rankine steam cycle, which required large steam generators to transfer the heat from the gas primary coolant to secondary water and steam. To overcome the challenge of cooling following a depressurization event and to achieve acceptable performance and safety, engineered measures had to be employed, further increasing the complexity and cost of these reactors making it difficult to compete economically; and the studies have not been followed by construction of fast gas cooled reactor plants. Recently, interest in gas cooled fast reactors (GFR) has been revitalized as the GFR emerged as one of three GEN-IV fast reactor candidates, sparking resurgence of new studies ranging from traditional designs with minor changes from earlier predecessors to more innovative solutions. The former group includes concepts based on advanced gas cooled reactors (AGRs) under investigation in Great Britain (Beaumont *et al.*, 2001; Gratton, 2003), which employ traditional CO_2-cooled pin core designs, and an indirect Rankine cycle with steam generators housed in a pre-stressed concrete pressure vessel (PCRV) and active safety systems.

More radical departures from earlier GCFR studies capitalize on recent advances in gas turbine technology and compact heat exchanger design, which provide the possibility to simplify the system by using a direct cycle, as in the CO_2-cooled direct cycle concept under development in Japan operating at a pressure of 7.1 MPa (Kato *et al.*, 2003), or the direct supercritical CO_2 (SCO_2) cycle operating between pressures of 20 and 7.9 MPa (Dostal *et al.*, 2001) proposed for a modular gas cooled fast reactor (Hejzlar *et al.* 2002). It is expected that significant simplification of the balance of plant and elimination of steam generators in combination with the higher efficiency of the Brayton cycle will reduce electricity generation cost. However, the challenge of post LOCA decay heat removal still remains a primary concern for the GFR concept, as was the case in the past. Hejzlar *et al.* (2002) addressed this issue by proposing a matrix core with dispersed particle fuel and showed that it was possible to design long-life GFR core that can survive depressurization accidents by relying on heat conduction and radiation, similar to its GT-MHR thermal counterpart. Although an excellent case for passive safety was made, it was also shown that low power density (8 kW/l) would result in unacceptably high fuel cycle cost.

The most extensive GFR investigations currently ongoing are focused on the GFR design for Generation IV service by French and U.S. institutions under the leadership of CEA and Argonne National Laboratory (ANL), respectively (Garnier *et. al.*, 2003), within the framework of the I-NERI