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Summary Decision Paper

Reference Modular HTGR Reactor Design Concept and Plant Configuration for Initial Applications

This paper summarizes the considerations in the selection of the High Temperature Gas-cooled Reactor (HTGR) design concept and plant configuration for the initial applications of modular HTGR technology for process heat co-generation and/or power generation. The INL generated end-user requirements (reference 1) have been a primary consideration for making the technology selection.

The Alliance represents the interests and views of our members that intend to mutually support and direct project plans to design, build, operate and use the HTGR technology. The Alliance provides a forum and focus to communicate industry needs and requirements and works in concert with the Idaho National Laboratory and others to seek out and promote industrial uses for HTGR technologies within the United States, North America and other continents around the world.

Commercialization of modular HTGR technology is essential to achieving evolving National and global environmental and energy policy goals. This technology fulfills the inherent safety features required by industry and offers performance capabilities that are well suited for a broad range of process heat co-generation and/or power generation applications. Related benefits include: 1) Reduced greenhouse gases (GHG) through large scale displacement of premium fossil fuels in a wide range of industrial and commercial applications; 2) Reduced reliance on imported oil and gas supplies as industry fuels; 3) Extending life of domestic oil and natural gas as strategic assets for transportation fuels, chemical feedstocks and other uses; 4) Sustainable expansion of American industrial manufacturing capabilities for energy intensive industries; and 5) Job creation within the U.S. supplying materials and equipment to construct and operate HTGR-based industrial infrastructure.

Reactor Design Concept

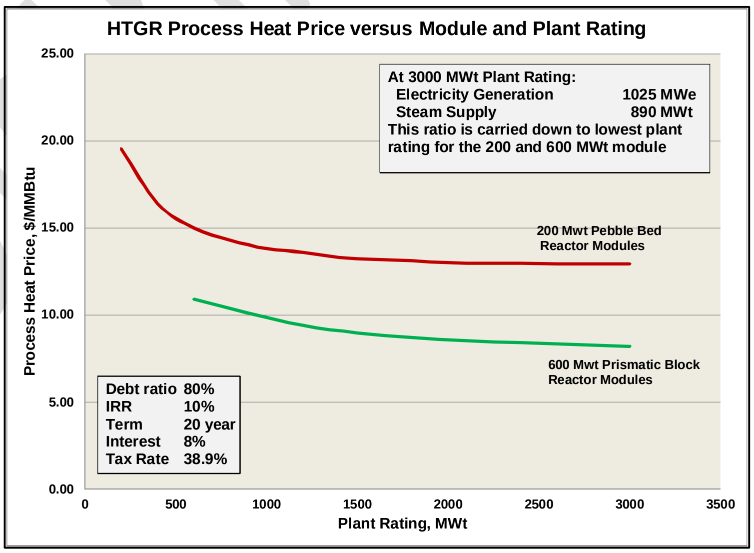
The concept selected is the prismatic reactor version advanced by AREVA, one of the members of the Alliance. AREVA has over thirty years of internal investment in pebble-bed HTGRs, and for the past ten years has significantly invested in the prismatic HTGR. AREVA has indicated (reference 2) a preference for the prismatic design concept as the basis for pursuing a high temperature reactor design for near-term industrial deployment. AREVA has indicated a willingness to bring their background intellectual property in both pebble-bed and prismatic HTGRs to the Alliance for further development. In addition to AREVA, other Alliance members including Westinghouse, SGL Group, and Technology Insights bring a wealth of technical and business experience to this development effort.

Reference 3 provides a detailed evaluation of over thirty specific design characteristics of two pebble bed reactor configurations and four prismatic reactor configurations that have been conceptualized as part of the work completed by INL during the NGNP Project. This included evaluation of the comparative advantages of the concepts for design, analysis, safety and operational performance attributes. The Alliance has evaluated the work completed by INL, and has reached the same conclusions that:

- There is currently no substantive technical differentiation that provides the basis for choosing the reactor design concept – whether pebble bed or prismatic
- There currently is no reason to believe that there will be a substantial difference in the costs and plant economic evaluations outside of the achievable power rating (see below)
- Either design concept can be successfully licensed

As identified during our process for evaluation, the only practical differentiators are associated with the anticipated difference in capital cost for the range of reactor concept ratings achievable for each and the business case for reactor design development and licensing. Addressing these two potential differentiators:

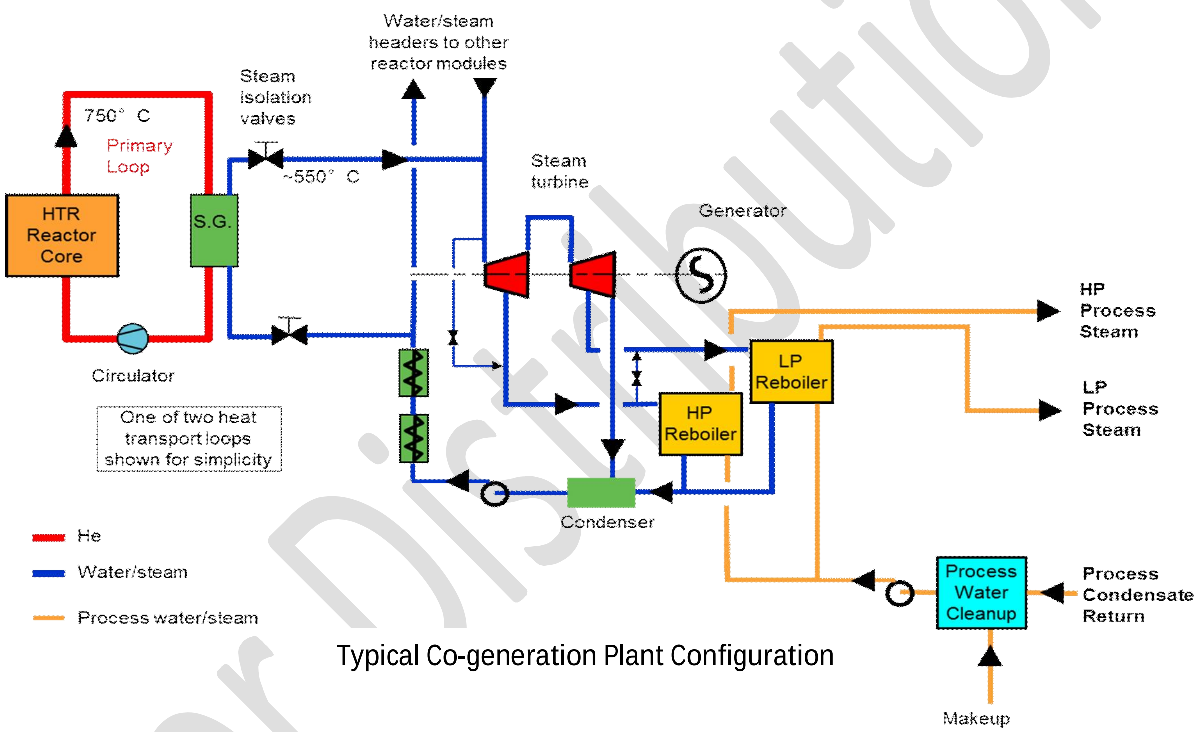
Economy of scale favors the prismatic design. Currently, the pebble bed reactor design concept is limited to a rating of about 250 MWt per module compared to the prismatic design limitation of about 625 MWt per module to achieve a practical reactor design that fulfills the inherent safety features for a modular helium-cooled reactor at the desired operating conditions. For a typical total installed plant capacity in the range 2400-3000 MWt (multiple modules), the effect of the expected difference in capital cost for a 250 MWt versus 625 MWt module rating based design is shown in the adjacent figure that shows a ~30% lesser energy price would be expected for the 625 MWt module rating prismatic reactor design concept compared to the pebble bed design concept.



AREVA has the technical and design capabilities to develop a HTGR for the process heat co-generation and generation markets. The specific terms and conditions under which such design and licensing will be pursued is being developed by the Alliance in its enterprise business plan. The Alliance plan will form and develop partnerships with constituents willing to make future commitments to invest. AREVA and others within the Alliance have technical and financial capabilities to develop, license, construct and operate a HTGR for such markets. Additional investors are being pursued to fully capitalize a venture in order to build an initial fleet of HTGR plants for industry.

Typical Co-generation Plant Configuration

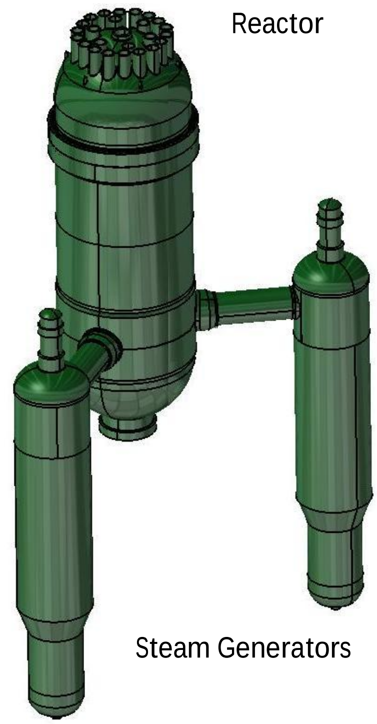
The near term industrial applications that extend the use of nuclear energy for non-electric missions have been shown to be primarily directed toward providing co-generated process heat in the form of steam and electricity. Examples of these potential industrial applications are summarized in References 5 and 6, with similar results for other applications evaluated by the Idaho National Laboratory that are not available in the public record. Common to these potential applications is "over-the-fence" provision of steam and electricity at conditions that indicate a required reactor helium outlet temperature in the range of 750-800 °C.



Typical Co-generation Plant Configuration

The nuclear process steam supply system, typical co-generation plant configuration and design/operating parameters preferred by AREVA are shown in the following figures from Reference 4, which are consistent with the conclusions drawn in References 5, 6 and 7. The Design Certification boundaries will be consistent with Reference 7.

AREVA Design - Nominal Parameters	
Fuel type	TRISO particle
Core geometry	102 column annular 10 block high
Reactor power	625 MWt
Reactor outlet temperature	750°C
Reactor inlet temperature	325°C
Primary coolant pressure	6 MPa
Vessel material	SA 508/533
Number of loops	2
Steam generator power	315 MWt (each)
Main circulator power	4 MWe (each)
Main steam temperature	566°C
Main steam pressure	16.7 Mpa



Nuclear Process Steam Supply System

Follow-on Applications

The reference steam cycle-based prismatic reactor is intended to satisfy a broad range of industrial heat needs while relying upon existing and available technologies for the reactor and plant. Follow-on applications are expected to require higher application temperatures and consequent greater design challenges. This could include different reactor vessel materials, an intermediate heat exchanger, or more advanced steam generators and other component changes to produce process heat in the form of higher temperature gas (e.g., supercritical carbon dioxide) and/or a hydrogen production capability (e.g., high temperature steam electrolysis). The Alliance business plan will indicate the path for development of these capabilities beyond the reference plant configuration. Licensing of the reference configuration should consider the most expeditious path to licensing for these follow-on applications.

References

1. INL/EXT-10-19887, *Key Design Requirements for the High Temperature Gas-cooled Reactor Nuclear Heat Supply System*, September 2010
2. Lommers, L. J., et.al., *AREVA HTR Concept for Near-Term Deployment*, Proceedings of HTR 2010, October 2010
3. INL/EXT-10-19565, *Basis for NGNP Reactor Design Down-Selection*, August 2010
4. AREVA Slide Presentation, Lommers, L. J., et.al., *AREVA HTR Concept for Near-Term Deployment*, HTR 2010, October 2010
5. INL/EXT-11-23239, *Integration of High Temperature Gas-cooled Reactor Technology with Oil Sands Processes*, October 2011
6. INL/EXT-11-23282, *Next Generation Nuclear Plant Project – Evaluation of Siting an HTGR Co-generation Plant on an Operating Commercial Nuclear Power Plant Site*, October 2011
7. INL/EXT-11-21605, *NGNP Nuclear-Industrial Facility and Design Certification Boundaries*, July 2011