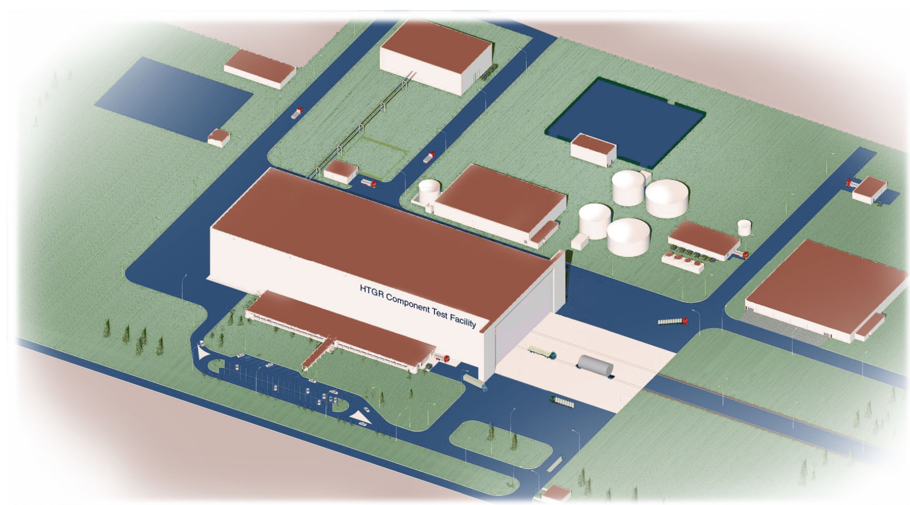
PLN-2763
(INL/MIS-08-14156)
Revision: 0

HIGH LEVEL REQUIREMENTS

High Temperature Gas Reactor (HTGR) - Component Test Facility (CTF)

April 2008



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High Level Requirements High Temperature Gas Reactor (HTGR) - Component Test Facility (CTF)

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Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

High Level Requirements
High Temperature Gas Reactor (HTGR) -
Component Test Facility (CTF)

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April 2008

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CONTENTS

TABLES

ACRONYMS

BEA	Battelle Energy Alliance, LLC
CTF	Component Test Facility
DDN	design data needs
DOE	Department of Energy
DRL	design readiness level
EPACT	Energy Policy Act
EPC	Engineering, Procurement, and Construction
FY	Fiscal Year
HELITE	Helium Loop for Innovative Technology
HTGR	High-Temperature Gas-Cooled Reactor
IHX	Intermediate Heat Exchanger
INL	Idaho National Laboratory
KVK	Komponenten-Versuchskreislauf (Components Test Circuit)
NEPA	National Environmental Policy Act
NGNP	Next Generation Nuclear Plant
NHI	National Hydrogen Initiative
OKBM	Afrikantov Experimental Machine Building Design Bureau
PBMR	Pebble Bed Modular Reactor
PCDR	preconceptual design report
PEP	Project Execution Plan
PHTS	Primary Heat Transfer System
PIRTS	Phenomena Identification and Ranking Tables
TRL	technology readiness level

High Level Requirements

High Temperature Gas Reactor (HTGR) -

Component Test Facility (CTF)

1. PROJECT JUSTIFICATION

The Next Generation Nuclear Plant (NGNP) project involves research, development, design, construction, and operation of a prototype nuclear plant intended for both high-efficiency electricity production and high-temperature industrial applications, such as hydrogen production. During various life cycle stages of the NGNP project, a number of systems, subsystems, assemblies, parts, and components need to be developed. To mitigate the technical risk associated with these systems, a large-scale test facility is required for the purposes of supporting the development of high-temperatures gas thermal hydraulic technologies, as applied in heat transport and heat transfer application in High-Temperature Gas-Cooled Reactors. Such applications include, but are not limited to, primary coolant, secondary coolant, direct cycle power conversion, reactor internals phenomena, intermediate and secondary heat transfer, and demonstration of processes requiring high temperatures (e.g., hydrogen production).

A pre-conceptual design of the NGNP was performed under leadership of three vendor teams: General Atomics, AREVA, and Westinghouse Electrical Company. Special studies performed by the vendor teams during the pre-conceptual design resulted in the identification of several engineering design data needs (DDNs). In addition, an initial effort was made to establish the technology readiness levels and design readiness levels (TRLs and DRLs) of key systems and components in accordance with the recommendations found in GAO-07-336. These DDNs, TRLs, and DRLs addressed aspects ranging from materials engineering, material qualification, and laboratory scale component testing up to, and including, full scale and engineering scale components.

Nearly 400 DDNs, using the pre-conceptual design reports (PCDRs) of the three vendor teams as a basis, were identified and listed. After closer evaluation of the DDNs, it was found that many of the technology needs could be addressed with specialized laboratory work, code committees, and other smaller-scale testing laboratories. The remaining DDNs must be accomplished in a facility capable of large-scale testing.

With all the DDNs, TRLs, DRLs, and NGNP lifecycle requirements taken into account, the CTF Mission Statement can be defined as being a facility that provides:

- Qualification and testing of large scale components in a high-temperature, high-pressure environment such as the:
    - Intermediate Heat Exchanger (IHX)
    - Ducting and insulation
    - Mixing chambers
    - Steam generator
    - High temperature valves
    - Specific application high-temperature instrumentation
    - Industrial hydrogen components
    - Helium circulators

  - Scaled reactor pressure vessel integration and reactor internals testing
  - Chemistry control systems for helium coolant with associated contaminants and impurities
  - Steady-state and transient analysis of coupled systems and components
- Design code development verification and validation collaboration
- Materials development and qualification
- Manufacturer and supplier evaluation and development.

2. ANALYSIS TO SUPPORT THE PROJECT

The 2005 Energy Policy Act charges the Department of Energy (DOE) and Idaho National Laboratory (INL) with demonstration of the HTGR technology for the production of electricity and hydrogen by 2021 in a NGNP demonstration. Meeting this commitment requires INL to coordinate the efforts of several commercial and governmental entities over a wide range of technical areas. A significant fraction of the technology development required to meet this commitment lies in the transfer of heat from the reactor to the processes used to produce electricity and hydrogen in NGNP, and ultimately in wider range commercial application of this technology following NGNP. This heat transfer occurs in the primary helium and secondary (and possibly tertiary) fluid flow loops. In NGNP, and in the early commercial applications of HTGR technology, the fluids in these loops will be gaseous (e.g., pure helium, a mixture of helium and nitrogen, or other gases such as CO_2). Current efforts for development of the technologies supporting design, construction, operation, and maintenance of these loops are concentrated in test loops at laboratory and pilot scales. Few facilities available worldwide or planned have the capacity to develop and test equipment at a scalable engineering level or at full scale.

A large hydrogen production plant has never been coupled to a HTGR, and the new hydrogen production processes under consideration are technically immature. Even high temperature electrolysis, which currently produces the largest volume of hydrogen as a pilot plant, will require scale-up of 15,000 times to demonstrate feasibility. The impact of transients and failures cannot be accurately analyzed with these large scaling factors and technical uncertainties. Therefore, to design engineered barriers, enable high temperature component development and to manage and mitigate these project risks, large scale modeling is needed. Evaluation of Phenomena Identification and Ranking Tables (PIRTs) developed for NGNP indentified that chemical releases, thermal events of the process application, failures of the intermediate heat transport system, and reactor events that provide a feedback path to the process application may have a major impact on the safety of the reactor. The NRC regulatory guide for Transient and Accident Analysis Methods considers scalability and validation as essential to demonstrating reactor safety in the licensing process. Hence, it is concluded that successful, timely design and licensing is unlikely without a large scale testing.

Development of a full-scale facility at INL provides this capability with the following advantages:

- Facilitates the INL role in coordinating, consolidating, and leading the development of the heat transfer and transport technologies needed to advance the application of HTGR and hydrogen generation technology
- Ensures the availability of the facility for NGNP and beyond development; the limited capacity and availability of other facilities (most of which are international and supporting other projects; see discussion below) could adversely affect NGNP schedule
- Improves the efficiency of technology development for NGNP and follow-on technology upgrades
- Establishes the DOE as a international leader in development of HTGR technologies
- Provides a means for operator/maintenance training, off-line trouble shooting of component and system problems during the operation of the NGNP and for technology development of programs and processes to ultimately support a growing commercial HTGR fleet

- Provides a long term U.S.-based facility for continued development of advanced technologies to increase the capabilities and broaden the applications of the HTGR and Hydrogen Generation.

DOE support of this initiative would demonstrate full commitment to development of HTGR and hydrogen generation well before NGNP is scheduled for operation. Demonstration of this commitment will support achieving industry participation in the Public-Private Partnership, which is central to success of the NGNP project.

To meet the project goals for testing and development of the heat transfer and transport technologies used in HTGR and hydrogen generation technology, a search and evaluation of existing capabilities was conducted by Westinghouse Electrical Company and AREVA. The criteria for the existing facilities and the results of the search and evaluation are presented in the following section.

2.1 Evaluation of Existing Facilities

To effectively address the technology development needs for the high-temperatures gas thermal hydraulic technologies, the facility must support component testing at power levels in the upper range of 25 MWt to 50 MWt, temperatures up to 950°C, pressures up to 9 MPa, and gas flow rates up to 20 kg/s. This would permit "full-scale" testing of the major components (e.g., IHX modules or scale models), and hydrogen process modules, (e.g., high-temperature electrolysis, sulfur-iodine or hybrid sulfur sulfuric acid decomposer modules) before installation in NGNP. For reference, the NGNP power may be as high as 500 to 600 MWt with primary flow rates of ~160 kg/sec to ~280 kg/sec, maximum outlet temperature of 950°C, and minimum inlet temperature of 350°C

Table 1 summarizes the capacities and status of existing, in development, and decommissioned high-temperature gas loops. A review of this table shows that the only test loops with close to full-scale test capacity include those in the Republic of South Africa supporting PBMR and in Russia for OKBM. The other large-scale loop, the German KVK loop, is no longer in operation. The remainder have much smaller capacities, (i.e., laboratory and pilot scale) designed for special purpose testing.

Although this table may not include every test loop in the world, it is understood that those with significant capacity that could meet the objectives of the CTF have been identified. Not only are these test loops located outside the United States, they are each related to a specific project, (e.g., the Helium Test Facility on Pebble Bed Modular Reactor (PBMR) development, the OKBM test facility on development of the GT-MHR). Accordingly, if NGNP or other related HTGR projects wanted to use the facility, that use would have to be coordinated with the schedule for the principal project in that country (e.g., coordinate with the PBMR testing in South Africa). Preliminary indications are that the current testing schedules have these facilities committed during the development time frame needed by the NGNP. As a result, in order for the NGNP to maintain the project testing schedule and not have an adverse impact on the Project's overall schedule for completion the CTF is needed. The scheduling and capabilities of the CTF facility must be flexible to adapt to evolutions in the technologies and emerging needs of those applying the technologies. It is not practical or desirable to rely on an offshore test facility over which the project has no control to meet these objectives. Accordingly, it is concluded that there is no current or planned fluid flow test facility that could be used to satisfy the mission needs of the CTF proposed herein.

Table 1. Summary of existing and planned fluid flow test facilities.

Facility	Country	Heating Power, MW	Flow Rate, kg/sec	Pressure, MPa	Tmax, Deg C	Availability/ Applicability	Comment
EVO (Turbine)	Germany	120	80	3	750	Dismantled.	
HHV (Turbine)	Germany	100	200	5	850	Dismantled.	
CT-1383 (Main Circulator)	OKBM (Russia)	n.a.	95	4.9	345	Dismantled/ prolonged storage	
KVK Loop	AREVA (Germany)	10.0	4	4	950	Dismantled.	Operated for 13,000 hours, 7,750 at 900 DegC 1981 to 1986.
CT-1312	OKBM (Russia)	15	4	5	965	Dismantled/ prolonged storage.	Test of IHX and Steam Generators
HENDEL	JAEA (Japan)	10	4	4	950	Dismantled.	
HTF – HTTU	Pelindaba (South Aftrica)	0.5	0.5	10	1600	Unavailable until 2012.	
HTF – HPTU	South Africa	0.1	2.8	5	35	Not applicable.	Test fluid is nitrogen.
HELITE Loop	CEA Cadarache (France)	1.2	0.4	8	950	See comment.	Design is complete; project is on hold awaiting funding
HELOKA	FZK, Karlruhe (Germany)	3 to 8	1.8 to 5.5	10	700	See comment.	In development, operational in 2009.

(grey)	Decommissioned
(green)	Operational
(blue)	Planned or in Construction

3. IMPORTANCE OF THE PROJECT AND IMPACT IF NOT APPROVED

A full-scale helium test facility is necessary to provide prototype testing and qualification of heat transfer system components (e.g., IHX, valves, hot gas duct), reactor internals, and hydrogen generation processing to mitigate the associated technical risks and to increase the technology readiness levels (TRLs) for these components. Since such a facility does not exist at the capacity needed for NGNP, it must be built. Failure to complete the facility in time to perform prototype testing could delay NGNP startup or could result in incomplete risk mitigation with potential adverse impact on plant performance if the NGNP was started up without prototype component testing and qualification.

4. CONSTRAINTS AND ASSUMPTIONS

4.1 Constraints

4.1.1 Operational Limitations

The initial use of the CTF facility will be in technology development support of the NGNP heat transfer system components; reactor pressure vessel and reactor internals; and high-temperature heat applications. The CTF will also provide a means for operator/maintenance training, off-line trouble shooting of component and system problems during the operation of the NGNP and for technology development of programs and processes that ultimately support a growing commercial HTGR fleet.

During the life cycle of the CTF the facility will then be open for use by the full range of suppliers, end-users, facilitators, government laboratories, and others in the domestic and international community supporting the development and application of HTGR technology and process heat applications.

4.1.2 Standardization and Standards Requirements

The CTF facility will be constructed within industry standards for industrial facilities, including hydrogen use and handling. Facilities will be constructed to meet local, state, and national codes, such as the International Building Code and National Electric Code.

4.1.3 Environmental, Safety, and Health Requirements

Under the INL Site's Integrated Safety Management System (ISMS), a project safety and health representative will be assigned to the project team and will support the project in implementing the project safety and health program.

As a high risk, high hazard, non-nuclear facility, safety must be an integral part of all CTF activities, from design through operation. Though STD-1189 and its use is required only for development of all DOE Hazard Category 1,2 , and 3 nuclear facilities, a graded approach will be applied for its use in the CTF project, ensuring appropriate safety considerations are applied to all phases of CTF development.

The CTF, located at the INL, will comply with applicable DOE Orders and INL Site requirements. DOE orders defining environmental related requirements include DOE Order 5400.1, "General Environmental Protection Program." Responsibilities for implementing the program are defined in a number of Battelle Energy Alliance, LLC (BEA) environmental program requirements documents and implementing control procedures.

4.1.4 Safeguards and Security Considerations

Security considerations will be included in the design to ensure the protection of intellectual property of vendors and agencies participating in testing at the facility. Construction at the INL may require evaluation of security considerations to determine if facility access control is required beyond what may be required by process safety or intellectual property considerations.

4.1.5 Legal and Regulatory Constraints and Requirements

The 2005 EPACT charges DOE and INL with demonstration of the HTGR technology for the production of electricity and hydrogen by the year 2021 in a NGNP demonstration. Failure to complete the CTF in time to perform technology development and prototype testing would delay NGNP startup or could result in incomplete risk mitigation with potential adverse impact on plant performance if the NGNP was started up without prototype component testing and qualification.

4.1.6 Stakeholder Considerations

The NGNP project will engage and energize both the domestic and international nuclear power industry in accomplishing the mission. Stakeholders involved in the core R&D program will be served by this facility for continued development of advanced technologies to increase the capabilities and broaden the applications of the HTGR.

The environmental community, a key stakeholder segment, will be engaged in the planning, review, and conduct of the CTF through the NEPA process. The State of Idaho, Idaho Falls, and the surrounding communities will also be engaged in the process and will be provided detailed information through the overall NGNP outreach program.

4.1.7 Limitations Associated with Program Structure, Competition and Contracting, Streamlining, and Use of Development Prototypes or Demonstrations

Competitive processes are expected to be used to the advantage of the project for the procurement of materials, components, and services. This concept will stimulate competition among technology providers and reduce development timelines.

4.2 Assumptions

High-level CTF project assumptions include:

- Funding will be available to support the project throughout its entire schedule to meet the accelerated milestone to support the NGNP.
- The CTF will not be physically connected to the NGNP facility.
- The CTF will be located at the INL.
- The CTF will be subject to the NEPA process

5. APPLICABLE CONDITIONS AND INTERFACES

5.1 Compatibility Requirements with Existing or Future Systems

The CTF must be designed to support the DOE Nuclear Hydrogen Initiative through testing of high-temperature heat exchangers, and test hydrogen generation processes using helium heat exchangers instead of direct heating.

The CTF will also provide valuable data and experience required to operate the NGNP, including control room simulation program data, verification, and validation data for methods/codes to support licensing and future commercial applications, and qualification of components installed in the NGNP.

The operational availability of CTF must coincide with the development schedule for the NGNP to meet the technology development needs for the heat transfer, process heat applications, reactor integrals, and hydrogen generation processes.

5.2 Project Interfaces

The CTF is part of the overall NGNP project and its cost integrated in the overall NGNP program costs. This facility will have many interfaces with the NGNP R&D and design teams to develop the testing requirements and configurations. The public-private partnership will act as a systems integrator in addition to being a partner with the government in the development of the facility.

The CTF will require a significant amount of electrical power to generate the heat and power requirements needed for “full-scale” component testing; therefore, regional power companies will be a vital interface and partner in the development of the infrastructure for the facility. This interface will provide challenges in terms of timely coordination and CTF completion schedule.

5.3 Resource Requirements and Schedule

The development of this facility is a key part of the NGNP development project with an early start date required to ensure its timely availability. The current NGNP schedule shows initiation of a facility Feasibility Study in Fiscal Year 08, which requires sufficient funding of the NGNP project to support this and other tasks starting the beginning of FY-08. Additional funding will be required in FY-09 to complete design, construction, and commissioning of the facility by the 4th quarter of FY 2012.

Pre-conceptual planning yielded an early estimated Total Project Cost of approximately $250 Million. For planning purposes, the acquisition of this facility is assumed to be funded by DOE, since the DOE funding cycle envelopes the schedule for potential funding by the Public Private Partnership, if the partnership chooses to fund the project. Following approval of Critical Decision -1 (CD-1), preliminary design would commence with PED funds in FY2010, followed by a request for Critical decision -2 (CD-2) approval. This approval would allow final design to be completed in FY2011, and would establish a performance baseline for the project. With a final design and performance baseline completed, a CD-3 approval request would be submitted to support facility construction in FY 2012. Line item construction funds would allow construction to commence in FY2012 and go through FY2013. Commissioning would follow, with a successful Operational Readiness Review prerequisite to CD-4, normal operations approval, which would be expected during the 1st qtr of FY2014.

Table 2. Schedule of funding requirements ($1,000)

	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	Total
Design (TEC)			$47,000	$14,800	0	0	$61,800
Construction(TEC)				$9,520	$107,230	$58,780	$175,530
OPC	$800	$7,370	$1,000	$1,000	$1,000	$1,500	$12,670
Total	**$800**	**$7,370**	**$48,000**	**$25,320**	**$108,230**	**$60,280**	**$250,000**

Key critical decision milestones are anticipated as follows, and will be fully developed as part of the Project Execution Plan (PEP):

- Critical Decision – 0: Completed December 2004 for the NGNP.
- Critical Decision – 1: Approval - planned 4th Q FY09
- External Independent Review: Planned 4^{nth} Q FY 2010
- Critical Decision – 2 Approval -planned 4th Q FY 2010
- Critical Deciison -3 Approval – planned 4th Q FY 2011
- Construction- 1st Q FY 2012 through 3rd Q FY 2013
- Critical Decision – 4: Planned approval 1st Q FY 2014

Note: If the CTF is funded by the Public Provate Partnership, this timeline for its commisioning could be compressed such that normal operations could commence in FY2013. DOE funding is limited by the Federal Budget cycle process, established by Congress.

6. DEVELOPMENT PLAN

A Project Execution Plan will be prepared for DOE's approval prior to commencing detail design, procurement commitments, and construction activities. This document will establish the baseline scope, schedule, and budget for the project.

The execution approach will utilize prequalified vendor teams to develop pre-conceptual design and technical recommendations. Conceptual design will then developed by a prequalified vendor team.

Following conceptual design, a procurement action will issued for preliminary and final design engineering, procurement, construction, testing, and startup. INL will perform the overall project management acting as the agent of DOE through conceptual design.

The project management requirements of DOE O 413.3A will be satisfied; In the timeline of Section 5.3, schedule has been allocated for the approval of each critical decision.

7. REFERENCES

Department of Energy, DOE O 413.3A, *Program and Project Management for the Acquisition of Capital Assets*

Department of Energy, GAO-07-336, *Report to the Subcommittee on Energy and Water Development, and Related Agencies, Committee on Appropriations, House of Representatives; Major Construction Projects Need a Consistent Approach for Assessing Technology Readiness to Help Avoid Cost Increases and Delays*, March 2007.

Energy Policy Act of 2005 (EPAct; H.R. 6)