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NGNP Component Test Facility

Conceptual Configuration, Cost, and Schedule Estimate

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

1. Introduction

A key activity necessary for completion of the NGNP Project is the development of a component test facility for the purposes of supporting development of high temperature gas thermal-hydraulic technologies as applied in heat transport and heat transfer applications in High Temperature Gas Reactors. Such applications include but are not limited to, primary coolant, secondary coolant, direct cycle power conversion, intermediate, secondary and tertiary heat transfer, and demonstration of processes requiring high temperatures, (e.g., hydrogen production).

This report builds on the previous work completed by AREVA related to the Mission Need Statement, CTF Justification, and Functional and Operational Requirements to develop and provide recommendations for the facility configuration, cost estimate and schedule. The information provided describes first each of two test loops; a 1MWt test loop to be built first, and a 30MWt test loop to be built later. Next the facility (i.e. building and associated equipment) is described. Next a high level estimate of the schedule for construction of the test loops and facility is provided. Finally, a rough order of magnitude cost estimate is provided.

2. Test Loop Configuration

2.1 *Functional and Operational Requirements*

The functional and operational requirements for the CTF are documented in AREVA Document 12-9072397-000, *High Temperature Gas Reactor Component Test Facility – Mission Needs and Requirements*, and incorporated here by reference (Reference 1). The CTF includes additional flexibility to support future testing (e.g. control rod drive mechanisms and hydrogen production) in addition to those defined for testing the indirect steam cycle.

2.2 *1 MWt Test Loop*

2.2.1 *Purpose*

The 1 MWt test loop, depicted in Figure 1, will be used for early validation of design options, Helium Purification System qualification and plate IHX preliminary testing. The loop will allow evaluation of thermal hydraulic, material, and design performance of selected components. The overall test program is summarized in Table 1 of Reference 1. The loop will enable testing of scale mock-ups to provide a basis for final recommendations on which equipment (e.g. IHX) concepts should be selected. Additionally, the loop will enable corrosion performance and component manufacturing methods to be tested in a representative He environment. The loop will also provide a flexible R&D platform to serve the needs of future HTGR development programs. Because it is proposed that the 1 MWt loop will be completed prior to the large test loop, it will also enable progressive development of the He process equipment manufacture supply chain, validation of technologies and design options which will be selected for the large loop, and provide valuable staff experience with He circuit operation.

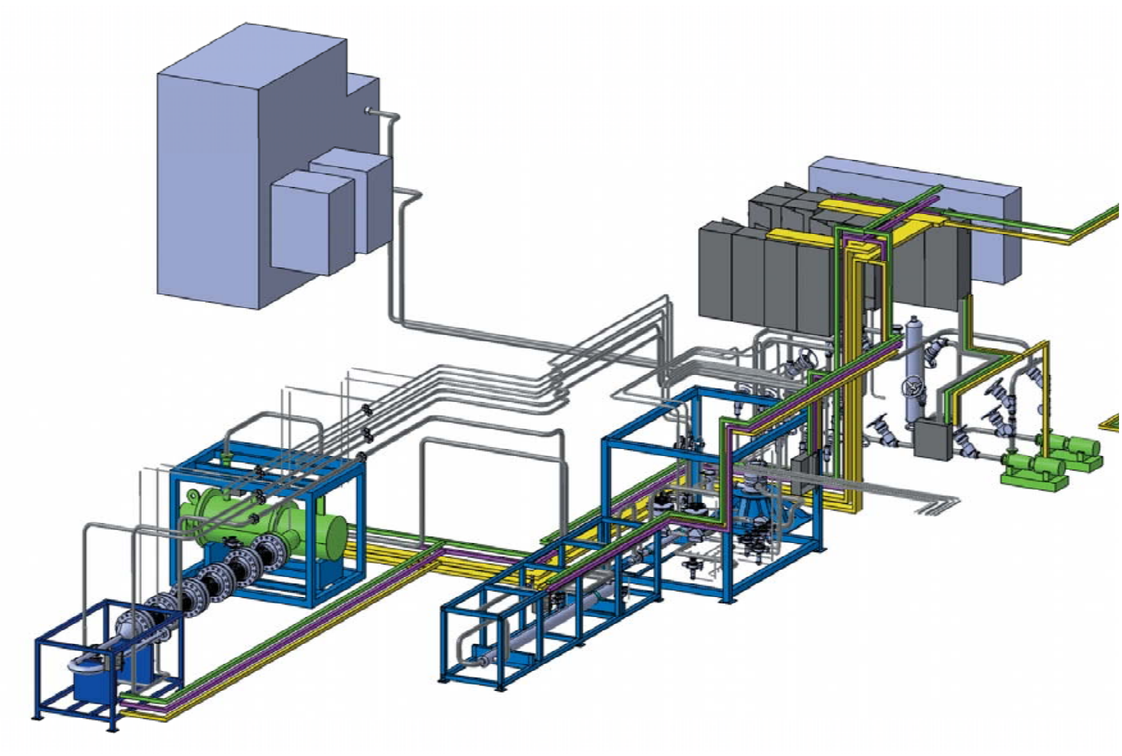


Figure 1 - Conceptual diagram of the 1MWt test loop proposed for CTF

2.2.2 *Description*

The 1 MWt test loop was based on the HELITE design (see Reference 1 for more information on the HELITE loop). The HELITE test facility operational plan included two phases:

- Phase 1: completion of the primary circuit with a maximum temperature of 850°C
- Phase 2: addition of second heater designed for the maximum temperature of 1000°C and a secondary gas circulation loop.

The HELITE design focused on phase 1, with provisions being taken for allowing an easy evolution towards phase 2. This design is based on the same approach.

The primary loop has a “figure-8” configuration with a recuperator heat exchanger, which allows operating the circulator at low temperature (60-120°C). The functional schematic of the phase 1 loop is illustrated in Figure 2.

The helium flow leaving the circulator is heated in the recuperator heat exchanger, then in the heater allowing reaching 850°C. It goes at this temperature into the high temperature (HT) test section and then, at the outlet of this test section is cooled in a cooler to about 500°C. At this temperature, helium enters into a medium temperature (MT) test section. After going through this test section, the helium is cooled by entering again into the recuperator heat exchanger and then into a cooler, in order to get back to the circulator at about 60°C.

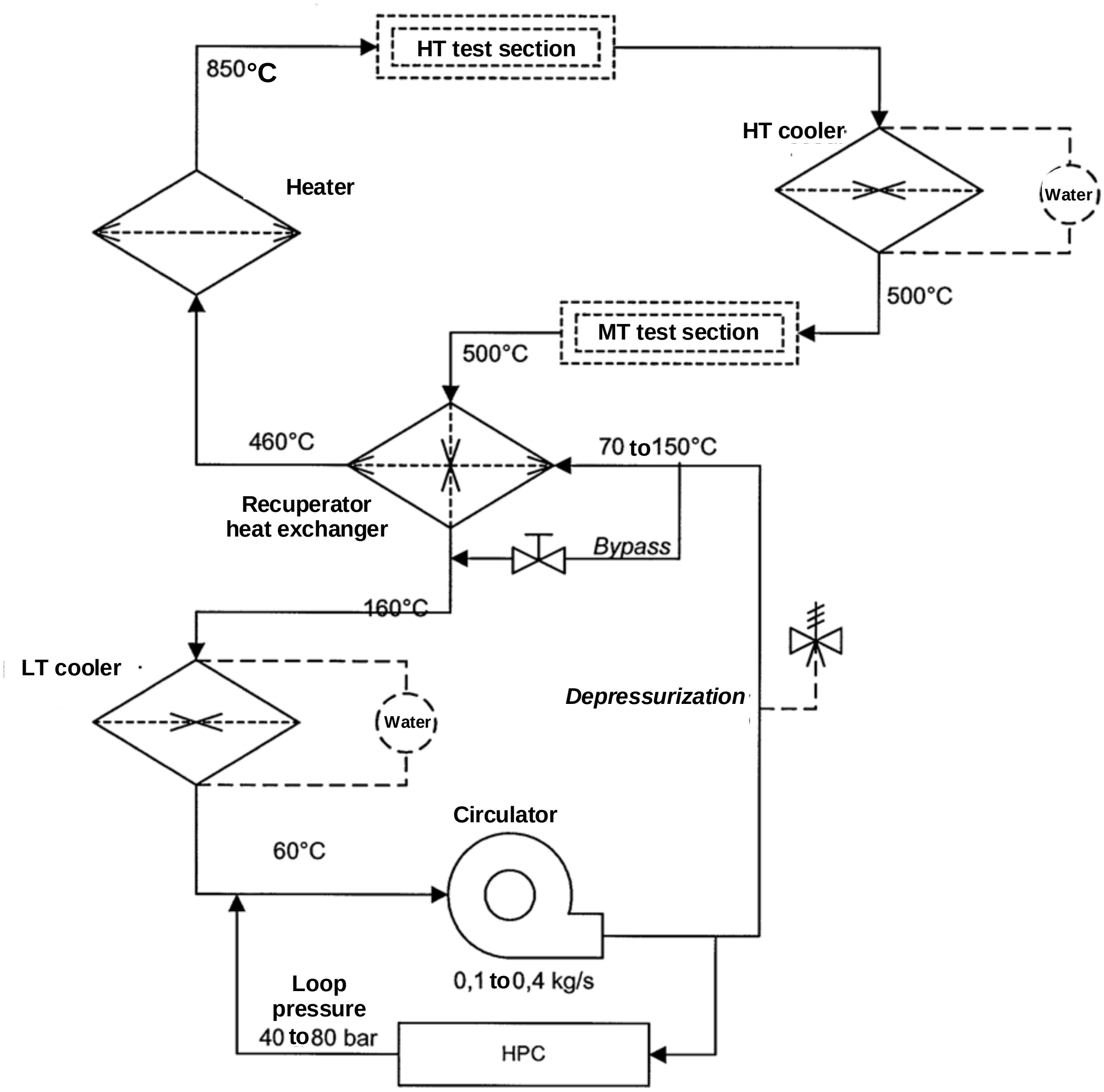
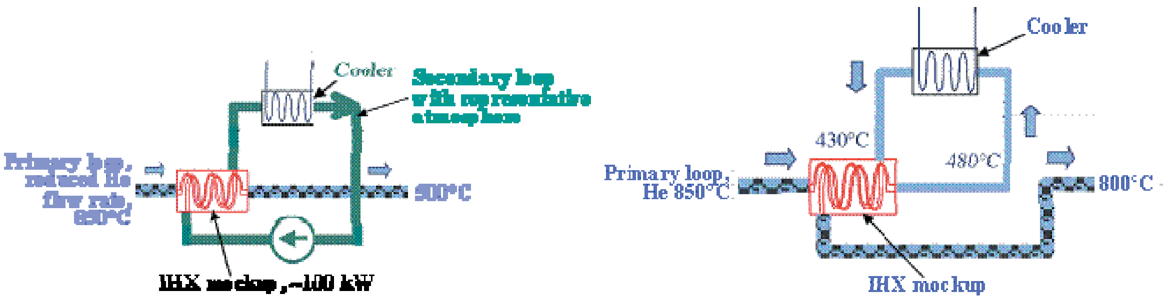


Figure 2 - Functional scheme of the 1 MWt loop, phase 1

The high temperature test section can be used to test both IHX mock-ups at operating temperature (850°C). The test section can be operated:

- With a small secondary loop in representative secondary atmosphere and reduced primary flow rate allowing only a limited power exchange (~ 100 kW) – see Figure 3 -a.
- With the primary helium re-circulated in the secondary side of the IHX mock-up, allowing testing of a higher power mock-up, but only for isobar behavior – see Figure 3 -b.



(a) (b)

Figure 3 - Schematics of potential 1MWt loop configurations

The interest of such tests is that it allows early tests of small IHX mock-ups supporting the selection of the most appropriate design concept before conducting more representative tests. Mock-up testing of the compact IHX is recommended in the 1 MWt facility, and also possibly of tubular IHX mock-ups, because of cost considerations.

In phase 2, an additional heater can be added in the primary loop for increasing its operating temperature to 1000°C, as well as a secondary circuit very similar to the primary circuit, in an “8” configuration, in order to perform IHX mockup tests in conditions representative of normal operation or simulating component failures (circulator or cooler failure, IHX channel choking or plugging...). The secondary loop shown in the right hand side of Figure 4 represents the HELITE secondary gas loop for a combined cycle, with operating parameters corresponding to the use of 20% helium, 80% nitrogen mixture. This configuration is more complex than is required for the He gas loop required for the indirect steam cycle recommended by AREVA for the NGNP, but it provides a reasonable basis for estimating the space that should be set aside to allow for future testing and the associated facility costs. The cost estimates in Section 5 do not include the costs associated with the phase 2 test loop. They only include the cost of providing the facility space and support services (e.g. HVAC).

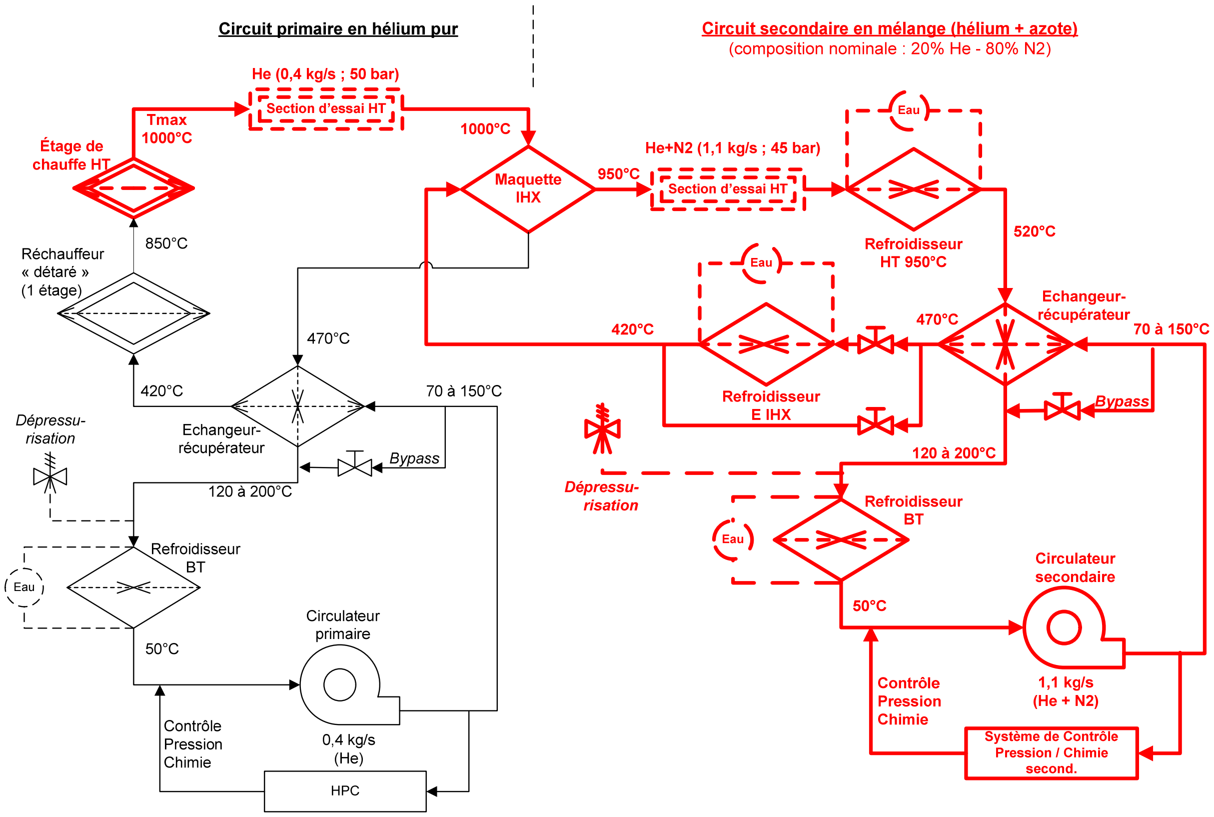


Figure 4 - Functional scheme of the 1 MWt loop, phase 2 mixed-gas loop test configuration

The complete loop, including both phases, occupies a space envelope of 35 m long by 30 m wide and 7.2 m high. Although a phased approach to loop construction is recommended, it is recommended that the facility be built to accommodate both the primary and secondary test loops to facilitate future expansion and provide flexibility for future programs of work.

The high temperature portion of the high temperature loop occupies a 20 m x 10 m space and will be enclosed in a concrete wall to provide personnel safety. The final design of the high temperature enclosure will be include a detailed industrial safety assessment. The height of the loop is dependent upon the components to be installed in the test section. But the height will remain limited because the main flow through the test section can be kept horizontal even if in the reactor it is vertical, as long as the effect of gravity can be ignored. Currently, it is envisioned that the largest component to be tested in this loop will be a section of the IHX which will be up to several meters high. Therefore, the part of the facility over the test section must be tall enough to accommodate this component, with appropriate provision for test component installation and replacement.

The test loop will be comprised of the following major components, for which the design data is listed in Table 1. Final component selection will be made during subsequent design phases.

- Circulator – The circulator will be designed to deliver 0.4 kg/s at 5.4 MPa, and to operate over a flow range of 0.1 to 0.4 kg/s [at 5 MPa] and pressures from 2 to 8 MPa [without limitations on flow rate]. A circulator has been developed and tested in France for this application.
- Recuperator – The recuperator is a high efficiency tube-shell heat exchanger. The design basis is 800 kW.
- The helium duct between the circulator and the recuperator heat exchanger will have connections to the helium purification and pressure control system.
- He Purification Cycle (HPC) and Pressure Control System – The He purification, chemistry and pressure control loop includes manual control valves and a gas circulation pump to maintain flow through the gas analyzers and purification system. This system, illustrated in Figure 5, includes subsystems dedicated to different functions. The first is the helium inventory and pressure control system (which includes a pressure relief system, with pressure relief valves and rupture disk, and isolation valves). The second is the purification system which uses classical processes to control the concentration of N_2, CO, CO_2, H_2O, H_2, O_2, NO and NO_2. This system will include filters, oxidizer, molecular sieves, activated carbon beds, gas supply (oxygen and He), and gas analyzers. Both the He inventory and pressure control system and the He purification systems are shown schematically in Figure 6.
- Gas compressor and storage - the gas compressor and storage unit will be designed for nominal operating pressure range of 0 to 8 MPa at a flow rate of 20 g/sec.
- Heaters - Electrical heaters in concentric cylindrical vessels. One lower temperature and one higher temperature system with independent electrical supply, control and monitoring. The design basis is a combined heater power of 1 MWt.
- Instrumentation, controls, and data collection – Temperature and pressure measurements will be recorded for the inlet and outlet of each of the test sections. Temperature and flow rates will be recorded at the outlet of the circulators. Temperatures will be measured at the inlet and outlet of each cooler and the recuperator. The flow rates and temperatures of the cooler inlet and outlets will be measured and recorded. The cooling water flow rate is used to control the circulator inlet temperature and the low temperature pipe temperature. The heater inlet and outlet temperatures and power levels will be recorded as well. The circulator speed would be measured and recorded. The circulator speed control is used to control the He flow rate in the loop. The helium purification, chemistry and pressure control loop includes manual sampling through small pipes connected to the primary circuit which connects to analytical instruments for measuring and recording N_2, CO, CO_2, H_2O, H_2, O_2, NO, and NO_2. There are manually operated valves for controlling flow through the He gas purification system; and two pressure regulating valves. There are a series of manual valves and by pass piping to route He flow through the analyzers and clean up processes. The pressure control system includes redundant independent pressure controls. Normal system operation is controlled using a pneumatic control valve set at the maximum pressure transient (approximately 0.3 MPa/s). A rupture disk is used to ensure that the pressure does not exceed the design pressure of 10 MPa. By-pass and isolation valves will be identified during detailed design
- Interfaces for the high and medium temperature test sections [>500 C] – The interfaces will be designed to cope with thermal expansion over the temperature range of operation.
- Mixed gas (He & N2) supply system – Piping, valves, instrumentation, and control system to blend the gases and deliver them to the loop (in the phase 2 mixed gas loop).

- Electrical Load Requirements – The main loads are 1.1 MW for electrical heaters (first module approximately 830 kW; high temperature module approximately 300 kW) and 70 KW for each gas circulator, for a total 1.2 MW (nominally 480 VAC).
- Coolers – Two tube and shell heat exchangers; A 830 kW high temperature unit [850 C inlet, 500 C outlet] and a 410 kW low temperature unit [150 C inlet and 50 C outlet].
- High temperature (> 500 C) piping of 9Cr stainless steel links the outlet of the electrical heater to the inlet of the HT cooler. Low temperature piping of stainless steel AISI 316 links the rest of the components. The high temperature piping will be 500 mm diameter and have internal insulation (i.e. Superwool) to maintain a design temperature of 400 C. The low temperature piping will be 100 mm diameter and have a design temperature of <500 C. The piping will be insulated to maintain contact temperatures below approximately 50 C and covered with aluminum sheet to protect the insulation. The layout of the piping and piping supports must accommodate thermal expansion while avoiding potentially damaging strain at interfaces with major components. The final design of piping and pressure boundaries will meet manufacturer and code requirements.
- Piping to the heat sink – an air cooling unit is located external to the building and will be connected via standard piping.

Table 1 Major Design Components for the 1MWt Test Loop

ID No.	Component	Type	Size D(m)xL(m)	Fluid	Flow rate (kg/s)	Capacity (MWt)	Design Temp (C)	Design Press (MPa)	Operating Temp (C)	Operating Press (MPa)	Other Criteria
1st Stage Heater	Phase 1 Heater	electric	TBD	He	0.4	1	1000	10	850	5	100 C/min. heat rate
2nd Stage Heater	Phase 2 Heater	electric	TBD	He	0.4	1.2	1000	10	1000	5	100 C/min. heat rate
R HT	High Temperature Heat Exchanger	shell-and-tube	TBD	water cooled	0.4	0.83	850	10	850 C inlet; 500 C outlet	5	Cooling loop to achieve 100 C/min.
B IHX	Low Temperature Heat Exchanger	shell-and-tube	TBD	water cooled	0.4	0.41	500	10	200 C in 50 C outlet	5	Cooling loop to achieve 100 C/min.
	Recuperator	shell-and-tube heat exchanger	TBD	He	0.4	0.8	500	10	520 C in; 200 C outlet	5	150 C inlet & 470 C outlet on cool side
PGC	primary gas circulator	compressor	TBD	He	0.4	TBD	50	8		5	0.38 MPa preasure drop
	High Temperature piping	9 Cr stainless steel with internal insulation	0.5 D	He	0.4		400 wall; 950 gas	10	200 C pipe wall		50 C contact surface

Table 1 Major Design Components for the 1MWt Test Loop

ID No.	Component	Type	Size D(m)xL(m)	Fluid	Flow rate (kg/s)	Capacity (MWt)	Design Temp (C)	Design Press (MPa)	Operating Temp (C)	Operating Press (MPa)	Other Criteria
	Low Temperature piping	stainless stell with external insulation	0.1 D	He	0.4		500	10	500 C pipe wall		50 C contact surface
HPC	He Purification and Pressure Control System	See figure 2 for details	TBD	He	0.04					8	see below
	Pressure Control	differential pressure actuated relief valves (2); rupture disk; disharge tank; isolation valves	TBD	He	TBD			10		8	pressure control set for 0.3 MPa/s transient; rupture disk set for 10 Mpa
	Purification System	See Figure 2	TBD	He	0.02			10		8	< 1 ppmV impurities
	He supply	tanks	TBD	He	10		ambient	10		8	sized for 30 MW test loop
	I&C	manual and pressure control valves; gas analyzers	TBD								impurities detect 2 to 100 Vpm

Table 1 Major Design Components for the 1MWt Test Loop

ID No.	Component	Type	Size D(m)xL(m)	Fluid	Flow rate (kg/s)	Capacity (MWt)	Design Temp (C)	Design Press (MPa)	Operating Temp (C)	Operating Press (MPa)	Other Criteria
SGC	Secondary Gas Circulator	off the shelf air circulator	TBD	20% He & 80% N2	TBD	1 MW	50	10		4.5	Added in Phase 2
E IHX	Medium Temperature Cooler	water cooled	TBD	20% He & 80% N2	TBD	TBD	470 C inlet; 420 C outlet	10		4.5	Added in Phase 2
B IHX [mixed-gas]	Cold Temperature Heat Exchanger	shell-and-tube	TBD	20% He & 80% N2	TBD	0.41	500	10	200 C in 50 C outlet	5	Added in Phase 2

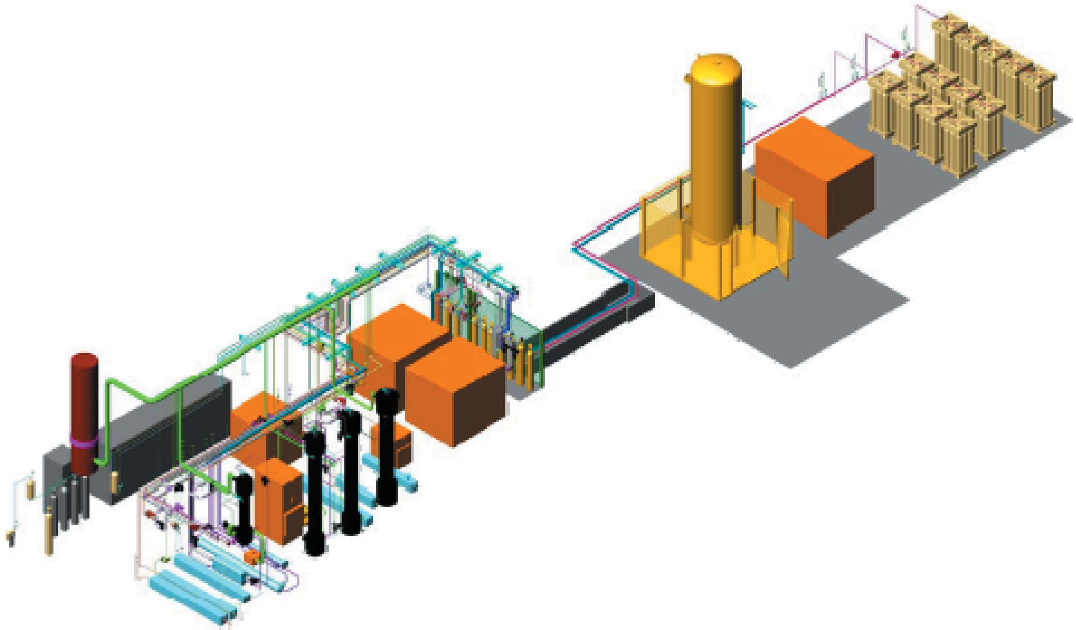


Figure 5 -Conceptual Diagram of the Helium Purification Cycle and Pressure Control System

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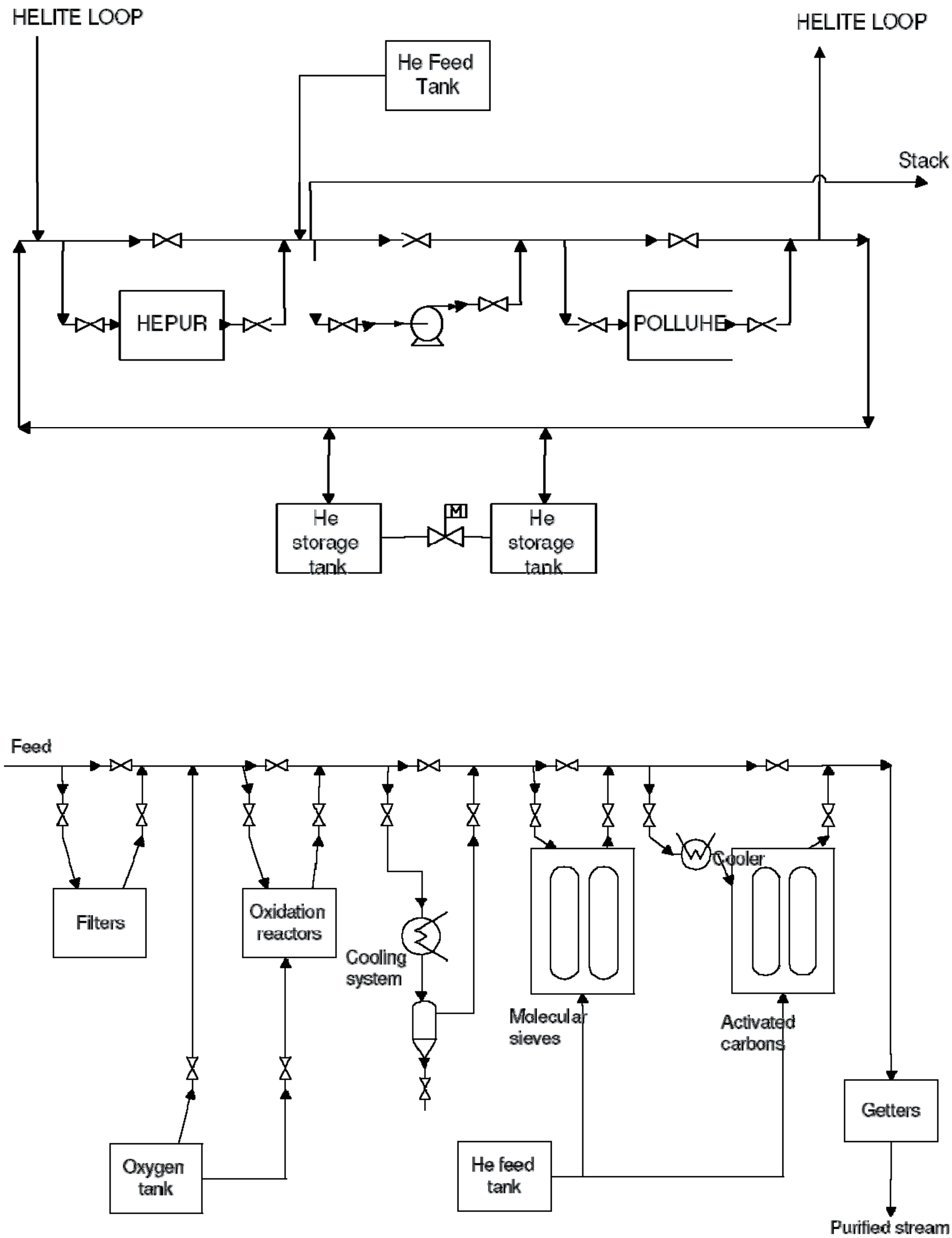


Figure 6 - He purification and pressure control system schematics

2.3 30 MWt Test Loop

2.3.1 Purpose

The 30 MWt test loop will be used for large scale testing and qualification of HTGR components (e.g. IHX, Steam Generator, Circulator) as well as for the follow-on design progression of NGNP and commercial HTR component qualification, pressure transients, and thermal-fluidic transients. The overall test program is summarized in Table 1 of Reference 1. Section 6.3 of the the NGNP Preconceptual Design Studies Report. (Reference 3) summarizes current design issues with the NGNP Primary Heat Transfer System.

2.3.2 Description

The system flow diagram for the 30MWt Test Loop and auxiliary systems are shown in Figure 7. This design is based primarily on the HENDEL Test Loop with reference also to the KVK Test Loop. The test system consists of three major loops and auxiliary systems as described below. For this early stage of planning, Figure 7 shows the tube IHX and the steam generator installed in the system as well as connections for testing of additional components without removal of the components shown. The final connection points and required flexibility will be determined in detailed design.

The primary test loop is comprised of the following major components and piping:

- Primary Gas Circulator (PGC) – The maximum flow rate is 10 kg/s. It may be feasible to develop a circulator with magnetic bearings for installation into the test loop. This would be preferable to match the circulator being proposed for the NGNP. However, an oil bearing and dry gas seal system for helium gas sealing between the rotor and casing will be carried forward to a decision point in the detailed design to reduce schedule and cost risk. Higher flow rates in the loop may be achieved by adding a supplemental surge tank for short periods of high flow via He injection to the loop.
- Heaters (EH1 and EH2) – two large capacity (15 MW) electric heaters (one at low temperature and one at high temperature) are shown in Figure 7. However, reliable high power, high temperature heaters can be difficult to obtain. Therefore, the option for a fossil fueled heater must remain open until a final decision can be made in detailed design.
- IHX (tubular type) – The heat exchanger capacity is 30MW. The configuration of the IHX should be similar to the IHX for the HTGR. The tube length in this model is assumed to be the same as that of HTGR and the number of tubes is about 1/10 of the HTGR design. Although included here, the cost of the IHX test component is not included in the estimate.
- Hot Gas Duct (HD) and Coaxial Double Pipe (CHD) and Low temperature piping – A single pipe with inner insulation is installed in the hot gas supply line. The CHD mock up is assumed to be the same diameter as the HTGR design and is installed between EH2 and WC1. Although included here, the cost of the CHD test component is not included in the estimate.

The secondary loop is comprised of following major components and piping,

- Steam generator (SG) – The heat exchanging capacity is 30MW. The configuration of the SG is assumed to be the same as the SG for the HTGR. The tube length in this model is assumed to be the same as that of the HTGR SG and the number of tubes is about 1/10 of the HTGR SG design. Although included here, the cost of the SG test component is not included in the estimate.

- Secondary Gas Circulator (SGC) – The maximum flow rate is 10 kg/s. This circulator may be the same design as the primary gas circulator to provide redundancy for maintenance and spares. However, if the gas blend in the secondary loop is similar in properties to air, a commercial design may be preferable.
- Hot Gas Duct (HD) and Low temperature piping – Similar to the primary loop components.

The function of the tertiary loop is to cool and control the SG system. It is comprised of the following major components and piping:

- Condenser (CD) and Condensate Tank
- Condensate pump
- Low pressure feed water heater and High pressure feed water heater (LPH, HPH)
- Deaerator (DR)
- High Pressure feed water pump (HPFP)
- Temperature Reducing Tank (TRT)
- Pressure Reducing Valves (PRV)

Component and Piping List

Table 2, Table 3, and Table 4 show the major component and piping list for the 30MWt loop.

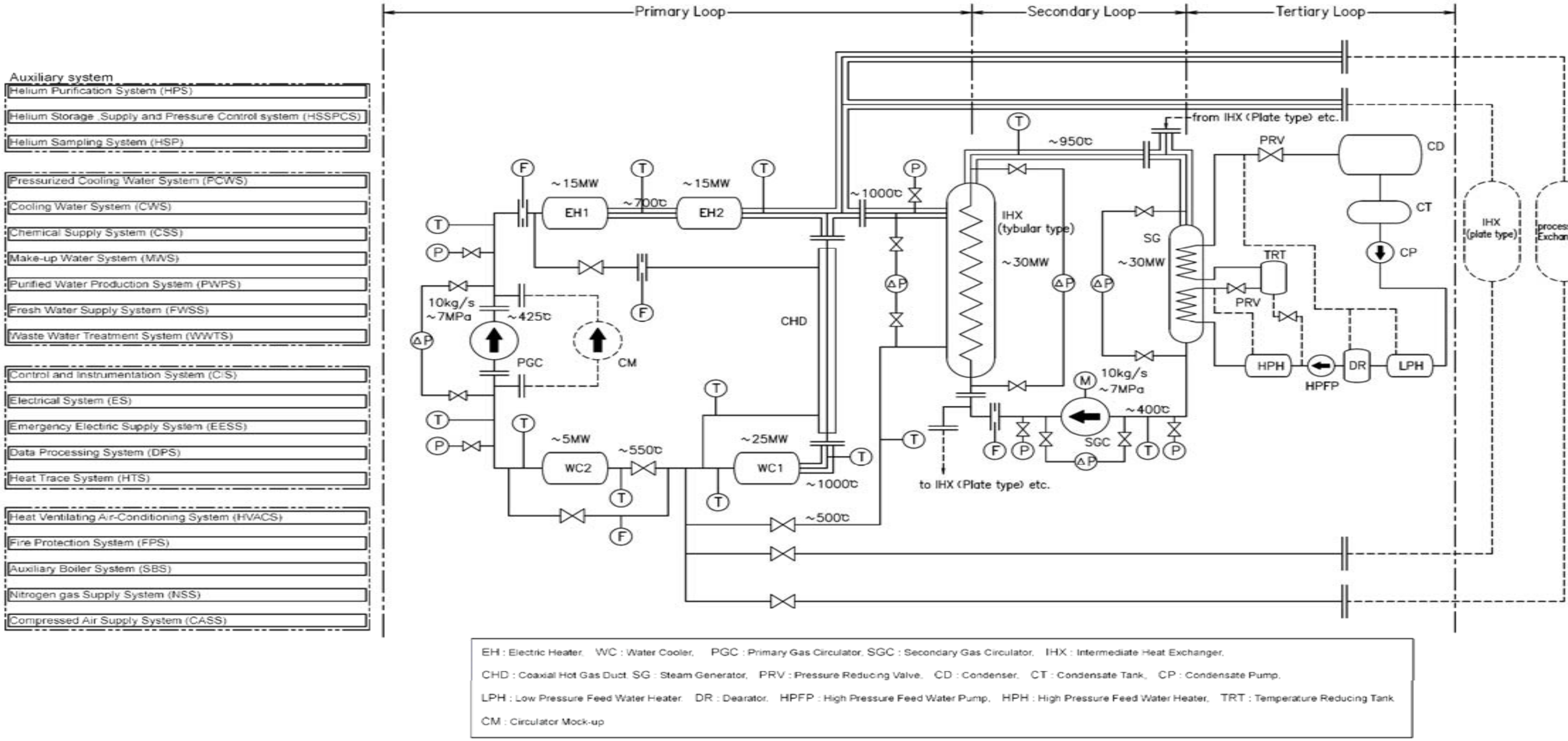


Figure 7 - Conceptual Layout of the 30MWt Test Loop Showing the Primary, Secondary, and Tertiary Loops

Table 2 Primary Loop Major Components

ID No.	Component	Type	Size D(m)×L(m)	Fluid	Flow rate (kg/s)	Capacity (MWt)	Design Condition of Vessel				Operating Condition of Vessel			
							Internal Press.		External Press.		Internal Press.		External Press.	
							Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)
EH1	Electric Heater 1	Vertical Direct electric piping heater	4.0×13.6	He	10.0	15	350	8	40	0.1	100	7	40	0.1
EH2	Electric Heater 2	Vertical Direct electric piping heater	2.9×11.0	He	10.0	15	350	8	40	0.1	100	7	40	0.1
WC1	Water Cooler 1	Vertical shell and tube type	3.5×10.6	He	10.0	25	350	8	40	0.1	100	7	40	0.1
WC2	Water Cooler 2	Vertical shell and tube type	1.2× 6.5	He	10.0	5	350	8	40	0.1	100	7	40	0.1
IHX	Inter mediate Heat Exchanger ‘tubular type)	Vertical helical coiled tube type	2.7×14.9	He	10.0	30	350	8	40	0.1	100	7	40	0.1
PGC	Primary Gas Circulator	Centrifugal, Oil bearing, dry gas seal type	TBD	He	10.0	TBD	450	8	40	0.1	425	7	40	0.1

Table 3 Secondary Loop Major Components

ID No.	Component	Type	Size D(m)×L(m)	Fluid	Flow rate (kg/s)	Capacity (MWt)	Design Condition of Vessel				Operating Condition of Vessel			
							Internal Press.		External Press.		Internal Press.		External Press.	
							Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)
SG	Steam Generator	Vertical helical coiled tube type	1.7×20.5	He/ Water/ Steam	Helium : 10.0 Water : 11.6	30	350	8.5	40	0.1	100	7.5	40	0.1
SGC	Primary Gas Circulator	Centrifugal, Oil bearing, dry gas seal type	TBD	Helium	10.0	TBD	450	8.5	40	0.1	405	7.5	40	0.1

Table 4 Primary Loop Piping

Piping name	Type	Nominal diameter (B)	Thickness (mm)	Flow rate (kg/s)	Fluid	Design Condition				Operating Condition			
						Internal Press.		External Press.		Internal Press.		External Press.	
						Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)	Temp. (ºC)	Press. (MPa)
Hot gas Duct (EH1~EH2)	Internal insulation single pipe	22	29	10	He	350	8	40	0.1	200	7	40	0.1
Hot gas Duct (EH2~IHX)	Internal insulation single pipe	26	34	10	He	350	8	40	0.1	200	7	40	0.1
Hot gas Duct (CHD~WC1)	Internal insulation single pipe	26	34	10	He	350	8	40	0.1	200	7	40	0.1
Coaxial Hot gas Duct (EH2~WC1)	Internal insulation double coaxial pipe	Outer pipe : 72 Inner pipe : 48	Outer pipe : 89 Inner pipe : 28	10	He	450	8	40	0.1	425	7	40	0.1
Low temp. pipe (PGC ~EH1)	Outer insulation single pipe	14	19	10	He	450	8	40	0.1	425	7	40	0.1
Low temp. pipe (IHX ~WC2)	Outer insulation single pipe	20	33	10	He	525	8	40	0.1	500	7	40	0.1
Low temp. pipe (WC1 ~WC2)	Outer insulation single pipe	20	50	10	He	575	8	40	0.1	550	7	40	0.1
Low temp. pipe WC2 ~PGC)	Outer insulation single pipe	14	19	10	He	425	8	40	0.1	400	7	40	0.1

3. Facilities Description

The CTF will be built in Idaho Falls, ID as a new stand alone facility which will be built in two phases:

Phase 1 – 1 MWt Test Loop and facility

Phase 2 – 30 MWt Test Loop and facility

The buildings will be a metal building with reinforced concrete structures around the high pressure and heat equipment as a safety barrier.

3.1 Test Loop Building

The Test Loop Building will house the 1MWt and the 30MWt test loops as well as auxiliary support equipment. It is proposed that the building be built using a phased approach; phase 1 would house the 1 MWt loop and phase 2 would expand the building to accommodate the 30 MWt loop. Separate controls, HVAC, and utilities are provided to the two phases of the building to allow the 1 MWt loop to operate while the 30 MWt loop is under construction. Figure 8 shows the layout that was developed to accomplish this. This layout allows use of common support areas and utility distribution systems. Figure 9 and Figure 10 show the 30 MWt He test loop primary circuit, which is the one that establishes the maximum height and utility service loads. During the development of the building layout it was determined that considerable cost savings could be achieved by modifying the original layout and locating the two tallest components off-set from the rest of the loop. This reduced the height of the rest of the building without significant changes to the length of high temperature pipe runs.

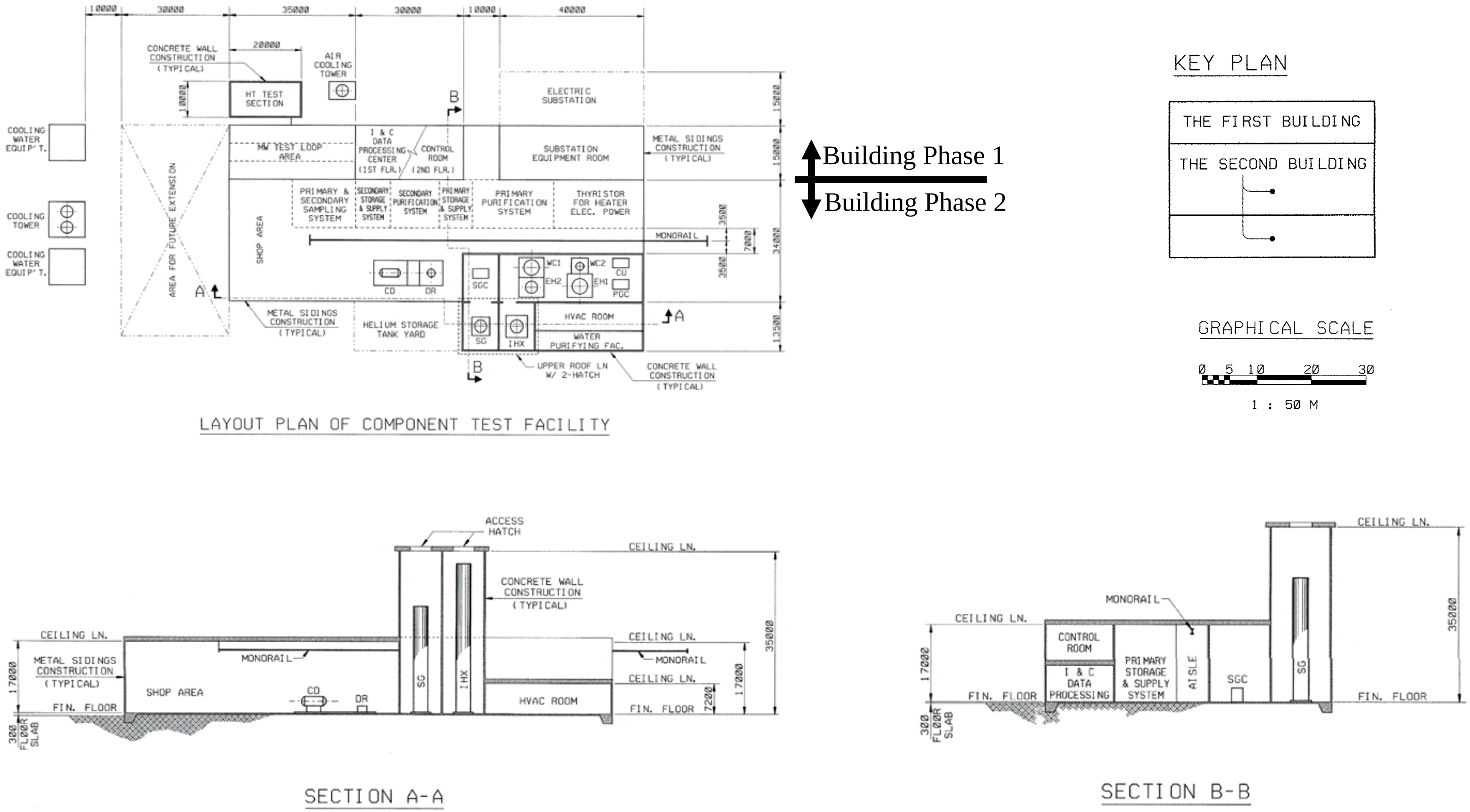


Figure 8 - Facility layout concept for the CTF

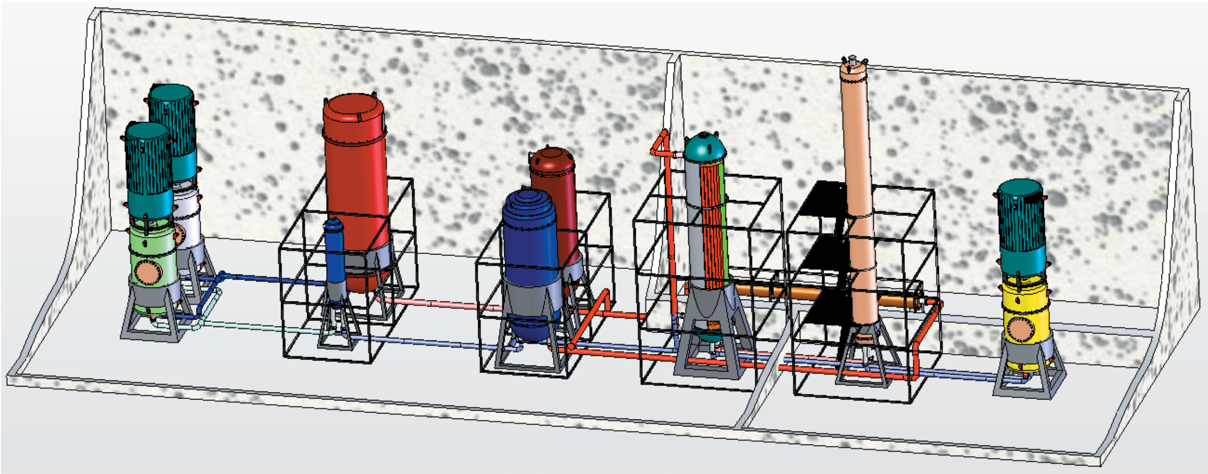


Figure 9 - View of the 30MWt test loop with coolers in foreground

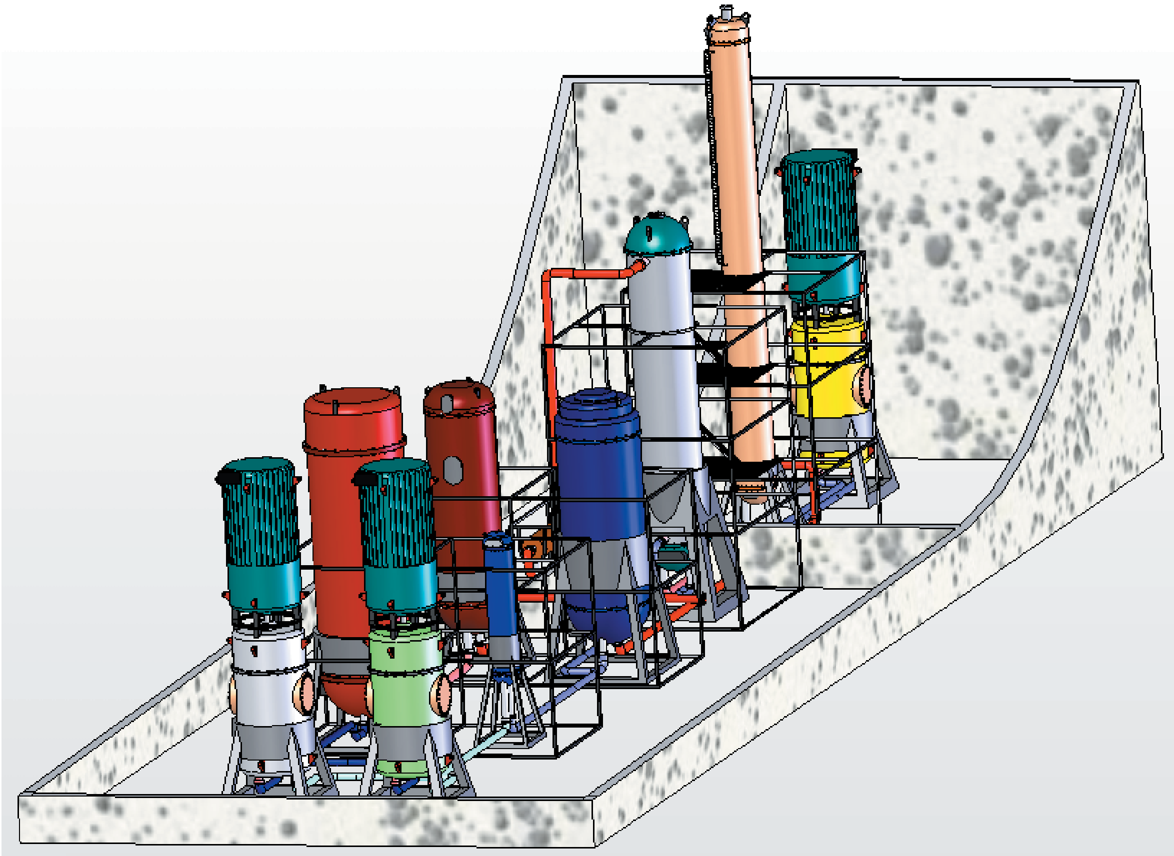


Figure 10 - View of the 30MWt primary loop from front

Upon completion of the building, the loops will be separated in such a way that simultaneous operation is possible. Shared systems between the loops will include standard building services such as electrical supply and HVAC systems. Other shared systems should be considered where such systems do not impact independent operation and result in cost or space savings. For example, shared warehouse space and gas storage systems can supply both loops without impacting independent operation. However, the control system, heat rejection system, and the HPC system should remain independent. The final selection of shared versus independent systems will be made during detailed design.

The design must incorporate ability for replacement and reconfiguration of test components and possible expansion in at least one direction. For example, Ref 2 illustrates reconfiguring the facility for generic materials testing and for testing the recuperator, a helium-water cooler mock-up, an IHX mock-up, and then expanding and reconfiguring equipment to test the IHX with mixed He & N_2 gas at representative temperatures (950 C). An area has been reserved outside the building for expansion, adjacent to the 1 MWt test loop and shop area, in the event that the CTF mission is expanded to include testing the hydrogen production process.

Continuous occupancy of the area of the building which houses the loops is not required. Therefore, this area will not require office space, restroom facilities, or other human occupancy features. However, access to the facility during testing must be accommodated. The HVAC system must be sized to remove the heat lost from the test loops during operation. Total heat loss to the building from both loops was estimated at ~4MW. The hot and pressurized sections of the test loops will be surrounded by concrete bunkers such that risk to occupants during operation is minimized. Careful consideration must be given to pressure wave propagation under accident scenarios during detailed design of the bunkered areas of the facility to ensure occupant safety.

The building will also house warehouse space for storage of equipment, spares and supplies, workshop space for light fabrication, test preparation work, and tool storage and a post test examination facility. The total size of the building, once both phases are complete, is 73,500 sq ft.

The building height will be segmented into three sections. The first section will be built during phase 1 construction. The ceiling height over the 1MWt loop 7.2m and the Control Room/Office space will have be 17m tall to allow for 2 floors. The second section of the building, to be built during phase 2 construction, will have a ceiling height of 17m except for the 35m high test bay which is sized for the steam generator and IHX. This area could also be used to test the control rod drive mechanism or other components identified in later phases of the NGNP reactor design. The phase 2 construction will include installation of a monorail for transport of large loop components from the loading dock to their location in the test facility.

3.2 Electrical and HVAC Rooms

The Electrical and HVAC Rooms will house the electrical distribution equipment and the building HVAC equipment. The total electrical feed requirements will depend heavily on final equipment selections during detailed design, however, for the purpose of this study a requirement of 35MW was assumed. The total size of the electrical and HVAC rooms is approximately 11,000 sq ft. It is proposed that the HVAC rooms be built large enough during phase 1 construction to accommodate equipment for the entire facility.

3.3 Control Room and Office Space

The control room and office space will be built during phase 1 construction as a two floor section of the building with instrumentation and control and data processing on the first floor and the control room and office space on the second floor. The total size of the space is 9000 sq ft.

3.4 Other Major Equipment

The other major equipment, which will be located outside the building are two heat sinks and He tank storage area. The first heat sink will be a dry cooler to remove the heat from the 1MWt test loop. The unit will be sized to remove both the heat from the loop cooler and the heat evolved to the rooms housing the loop. The second heat sink unit will be a cooling tower to remove the heat from the 30MWt test loop. As with the dry cooler, the cooling tower will be sized to remove the heat from the loop coolers and the heat evolved to the rooms housing the loop.

4. EPC WBS and Schedule

4.1 WBS

See Appendix 1 for the high level WBS, showing how the project should be rolled up for maintaining proper project control

4.2 Facility Schedule

The CTF schedule for completing the facility and phase 1 of the 1 MWt and 30 MWt Test Loops is shown in Figure 11. This schedule includes the time from start of design through readiness to conduct first component testing. Project closeout and handover activities where assumed to occur after commissioning and are not included in the schedule. Note that the schedule for the test loops is based on experience building similar systems in France and Japan, therefore, local influences on schedule must be evaluated in the next phase of design. Also, the schedule for the test loops has not been integrated with the facility schedule. Finally, the CTF schedule must be integrated with the overall NGNP component development and testing schedule to assure it is available to meet the design data needs in line with overall project requirements. This is expected to be developed during the next phase of design when more detailed plans for testing can be laid out for specific components, when they will be ready for testing, the expected duration of the tests, which loop is required, and so on.

4.2.1 1 MWt Test Loop

The major schedule milestones for the 1MWt test loop are as follows. All dates are After Receipt of Award and depend on obtaining access to the HELITE Loop design. Options for schedule acceleration have not been considered in this study.

- Completion of detailed design - 4 months [based on updating existing HELITE design for the 1MWt loop]
- Completion of Procurement Initiation - 8 months [including source selection].
- Completion of facility construction and installation of the primary He test loop – 31 months

- Completion and connection of the mixed gas secondary loop and test at 950 C with IHX mock-up – 52 months

4.2.2 30 MWt Test Loop

Based on experience from design and construction of the HENDEL and KVK loops, the critical path items can be broken down as follows for the 30MWt loop.

Key dates in the Phase 1 development schedule following project start are:

- Start date for procurement of long lead-time items: 9 months
- Completion of site erection: 43 months
- Completion of commissioning: 48 months

The key dates in the Phase 2 development schedule following project start are:

- Start date for procurement of long lead-time items: 33 months
- Completion of site erection: 66 months
- Completion of commissioning: 69 months

The major schedule risks are associated with procurement of major critical materials (e.g. forgings, Ni-based heat resistant alloy, large capacity heater elements and electrical equipment)

ID	Task Name	Duration	Start	Finish
1	**NGNP Component Test Facility**	**1051 days**	**5/1/08**	**5/10/12**
2	**Test Loops**	**1051 days**	**5/1/08**	**5/10/12**
3	**1 MWt Loop (Primary Loop)**	**675 days**	**5/1/08**	**12/1/10**
4	Conceptual Design	0 days	5/1/08	5/1/08
5	Preliminary Design	0 days	5/1/08	5/1/08
6	Detailed Design	88 days	5/1/08	9/1/08
7	Place Orders	200 days	7/2/08	4/7/09
8	Procurement and Construction	411 days	11/3/08	5/31/10
9	Installation	132 days	3/31/10	9/30/10
10	Commissioning	44 days	10/1/10	12/1/10
11				
12	**30MWt Loop (Primary Loop)**	**1051 days**	**5/1/08**	**5/10/12**
13	Conceptual Design	109 days	5/1/08	9/30/08
14	Preliminary Design	72 days	10/1/08	1/8/09
15	Detailed Design	278 days	1/9/09	2/2/10
16	Place Orders	404 days	2/6/09	8/25/10
17	Procurement and Construction	523 days	9/10/09	9/12/11
18	Installation	262 days	2/9/11	2/9/12
19	Commissioning	65 days	2/10/12	5/10/12
20				
21	**Facilities**	**1047 days**	**5/1/08**	**5/4/12**
22	**Building 1**	**754 days**	**5/1/08**	**3/22/11**
23	Design Engineering	375 days	5/1/08	10/7/09
24	Construction Mobilization	15 days	2/2/09	2/20/09
25	Clearing and Grubbing	15 days	2/23/09	3/13/09
26	Site Survey	30 days	2/23/09	4/3/09
27	Environmental Testing	125 days	3/16/09	9/4/09
28	Site Grading and Underground	67 days	9/7/09	12/8/09
29	Long Lead Procurement	250 days	8/3/09	7/16/10
30	Construction	250 days	12/9/09	11/23/10
31	Construction Startup	85 days	11/24/10	3/22/11
32				
33	**Building 2**	**835 days**	**2/23/09**	**5/4/12**
34	Design Engineering	375 days	2/23/09	7/30/10
35	Construction	375 days	8/2/10	1/6/12
36	Construction Startup	85 days	1/9/12	5/4/12

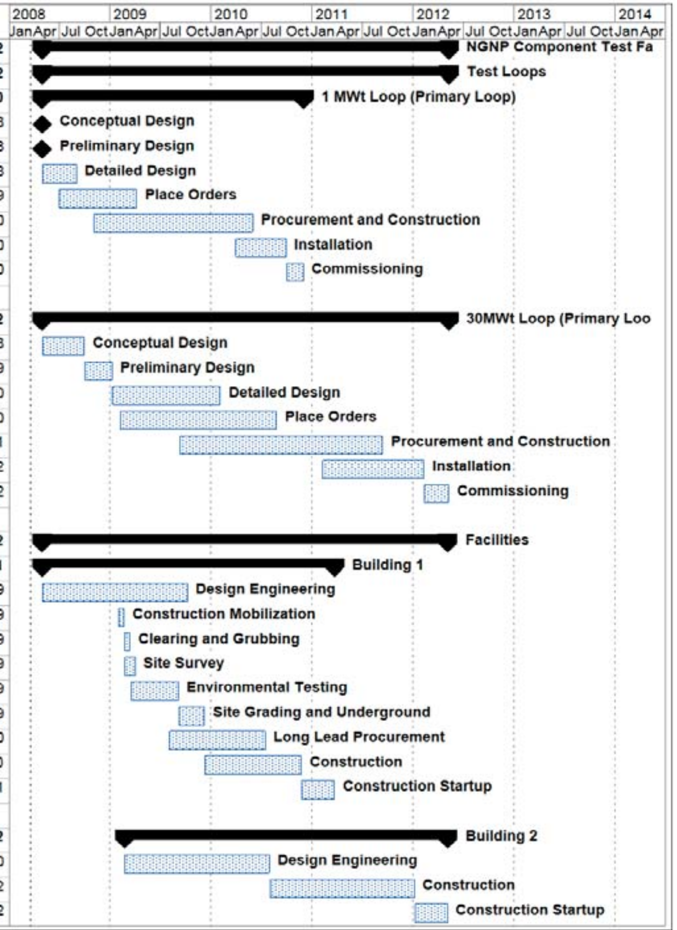


Figure 11 - Schedule for CTF Test Loops and Facility

5. Rough Order of Magnitude Cost Estimate

5.1 Basis of Estimate

A cost estimate for the CTF was developed using appropriate estimating techniques, depending on available information. These techniques include specific analogy, parametric, cost review and update, and expert opinion, as appropriate for the given part of the estimate. Assumptions required to achieve the estimate are documented herein. Due to the short time allotted for the task, iteration on design information and assumptions was very limited. Therefore, the information presented here should be viewed as early draft information which enables rough cost estimating only. The estimated costs provided are Rough Order of Magnitude costs (-10% to +100%) based on AREVA experience building similar facilities. These estimates must be validated during subsequent design phases when the test program is better defined, equipment selections have been made, final building requirements and layout have been established, the building site is selected, and so on. Contingency was applied to the estimate in proportion to the confidence in the supporting information but generally ranged from 30-50%.

5.2 Cost Estimate Breakdown

The total cost for the facility including phase 1 of both test loops and the buildings is estimated at $265.9M. This cost assumes that adequate electrical supply is available at the construction site, and includes all electrical distribution for the building and equipment. Heat rejection equipment is included in the estimate. The estimated costs can be broken down as follows:

5.2.1 1 MWt Test Loop

Engineering: $1.4M

Procurement and Construction: $10.9M

Installation and Commissioning: $3.5M

Total Cost: $16.0M

The low engineering cost for the 1MWt test loop assumes that access to the HELITE design is available. No cost is included for technology transfer or other costs which may apply to obtaining access to the HELITE design, component test and qualification data, operating procedures, test plans, or test specifications.

5.2.2 30 MWt Test Loop

Engineering: $49.0M

Procurement and Construction: $81.6M

Installation and Commissioning: $52.2M

Total Cost: $182.8M

The relatively high estimate for engineering and installation and commissioning allows for the development of components (e.g. circulator) and the large effort associated with adaptation of previous designs to meet the NGNP mission needs.

5.2.3 Facilities

The facility cost estimate can be broken down into the following elements. These costs are inclusive of facility design, excavation, backfill, compaction and material hauling during site preparation, all materials and labor for facility construction, and facility startup activities. The estimate excludes costs associated with permitting, licensing, NEPA compliance or other similar costs. The cost for phase 1 includes building the HVAC, Electrical, and Control and Office spaces large enough to accommodate equipment for both phases of the building.

Phase 1: $11.8M

Phase 2: $55.3M

Total Building Cost: $67.1M

5.3 Assumptions and Qualifications

The information in this report is based on the recommendations made in the NGNP Pre-conceptual Design Studies Report (Reference 3). That document identified risks and research and development needs for various components. Contingency has been added to the cost estimates based on confidence levels in the estimate.

Facility estimates include costs of engineering, procurement and construction of the facility and exclude costs associated with permitting, Environmental Impact Statement Preparation, and facility site geotechnical studies.

Required utilities were assumed present at the site prior to construction.

Cost estimates are exclusive of test elements (e.g. IHX, SG)

Test loop estimates are provided in 2007 dollars. Allowance should be made for the large price escalation in metals (~20%) over the 12 to 18 months prior to this report.

The 1 MWt test loop estimate does not include potentially applicable technology transfer or other fees associated with obtaining the Helite design.

Reconfiguring the 30MWt test loop as a “figure 8” would add the cost of a recuperator, additional piping, and a larger building.

Facility estimates are provided in 2008 dollars.

Facility will incorporate over pressure controls which meet applicable safety requirements.

At this time, the cost estimate does not reflect any cost sharing or cost responsibilities between partners involved. Once the scope and agreements have matured, the estimate can be revised to reflect possible cost savings to the project.

For facility estimates, INL provided the craft wage rates in an April 18, 2007 e-mail. Wage rates are fully burdened with FICA, SUI, WC, etc and also include a $19.00 per diem cost. Rates are escalated to 2008.

The cost estimate does not consider or address funding restrictions. It is assumed that sufficient funding will be available in a manner allowing optimum usage of that funding as estimated and scheduled.

No allowances for complications due to extreme weather have been included in this estimate.

This project does not include any monies for quality engineering or assurance reviews or input.

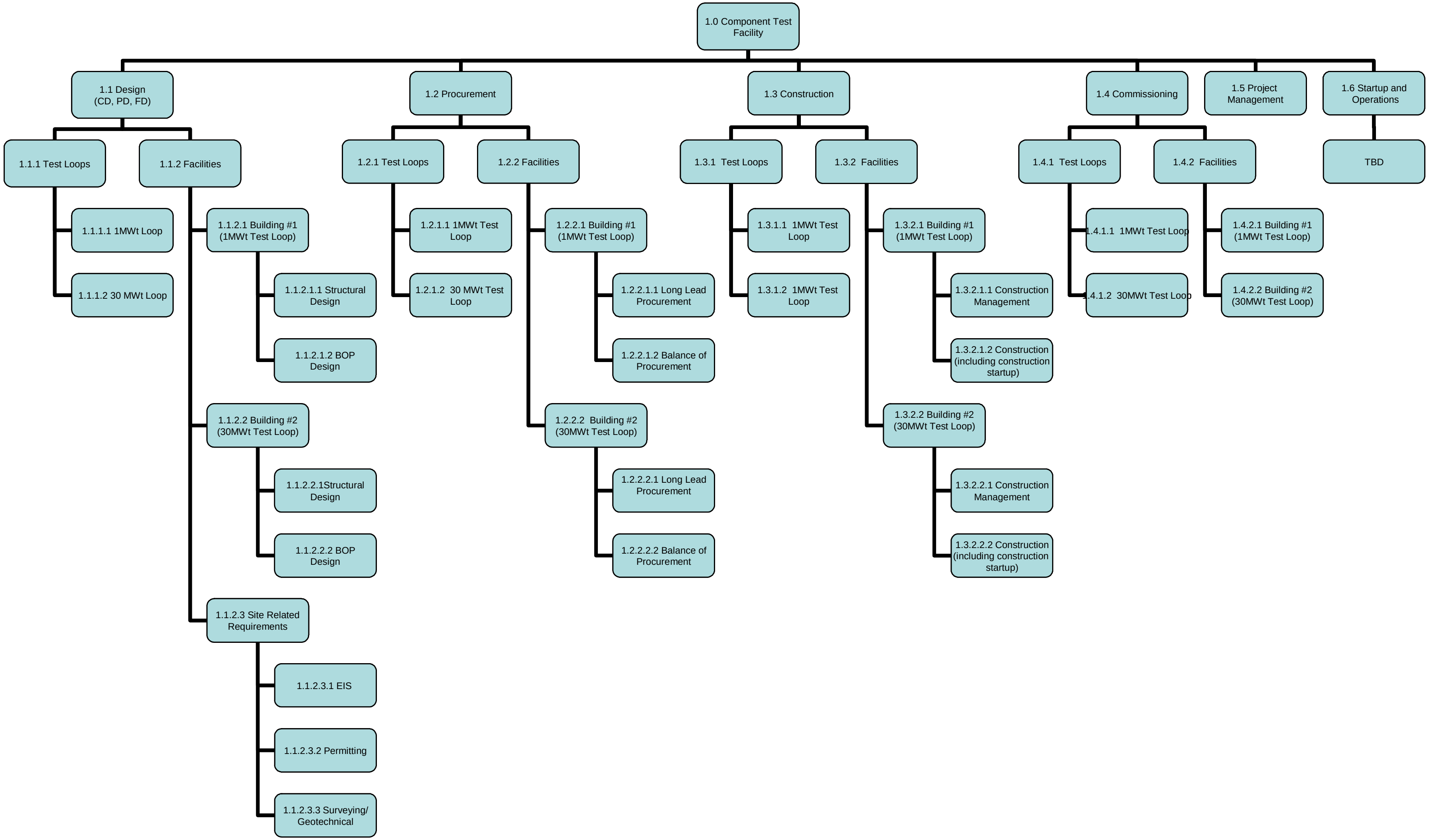
For facility construction, a subsistence allowance is included based on approximately 60% of craft as “travelers”.

It has been assumed only one mobilization and demobilization will be needed to construct the facility. Once the mobilization has been completed, the work will proceed continuously until it has been completed. Crews will demobilize from the project at the completion of construction and startup.

6. References

1. *High Temperature Gas Reactor Component Test Facility – Mission Needs and Requirements,* AREVA Document No. 12-9072397-000
2. *Helium Technological Loop for High Temperature Gas Cooled System Technology Development,* Proceedings of ICAPP, Seoul, Korea, May 15-19, 2005, Paper 5413
3. *NGNP Preconceptual Design Studies Report*, AREVA Document No. 12-9051191-001

Appendix 1: High Level EPC WBS


1.0 Component Test Facility
1.1 Design (CD, PD, FD)
1.2 Procurement
1.3 Construction
1.4 Commissioning
1.5 Project Management
1.6 Startup and Operations
1.1.1 Test Loops
1.1.2 Facilities
1.2.1 Test Loops
1.2.2 Facilities
1.3.1 Test Loops
1.3.2 Facilities
1.4.1 Test Loops
1.4.2 Facilities
TBD
1.1.1.1 1MWt Loop
1.1.1.2 30 MWt Loop
1.1.2.1 Building #1 (1MWt Test Loop)
1.1.2.1.1 Structural Design
1.1.2.1.2 BOP Design
1.1.2.2 Building #2 (30MWt Test Loop)
1.1.2.2.1Structural Design
1.1.2.2.2 BOP Design
1.1.2.3 Site Related Requirements
1.1.2.3.1 EIS
1.1.2.3.2 Permitting
1.1.2.3.3 Surveying/ Geotechnical
1.2.1.1 1MWt Test Loop
1.2.1.2 30 MWt Test Loop
1.2.2.1 Building #1 (1MWt Test Loop)
1.2.2.1.1 Long Lead Procurement
1.2.2.1.2 Balance of Procurement
1.2.2.2 Building #2 (30MWt Test Loop)
1.2.2.2.1 Long Lead Procurement
1.2.2.2.2 Balance of Procurement
1.3.1.1 1MWt Test Loop
1.3.1.2 1MWt Test Loop
1.3.2.1 Building #1 (1MWt Test Loop)
1.3.2.1.1 Construction Management
1.3.2.1.2 Construction (including construction startup)
1.3.2.2 Building #2 (30MWt Test Loop)
1.3.2.2.1 Construction Management
1.3.2.2.2 Construction (including construction startup)
1.4.1.1 1MWt Test Loop
1.4.1.2 30MWt Test Loop
1.4.2.1 Building #1 (1MWt Test Loop)
1.4.2.2 Building #2 (30MWt Test Loop)