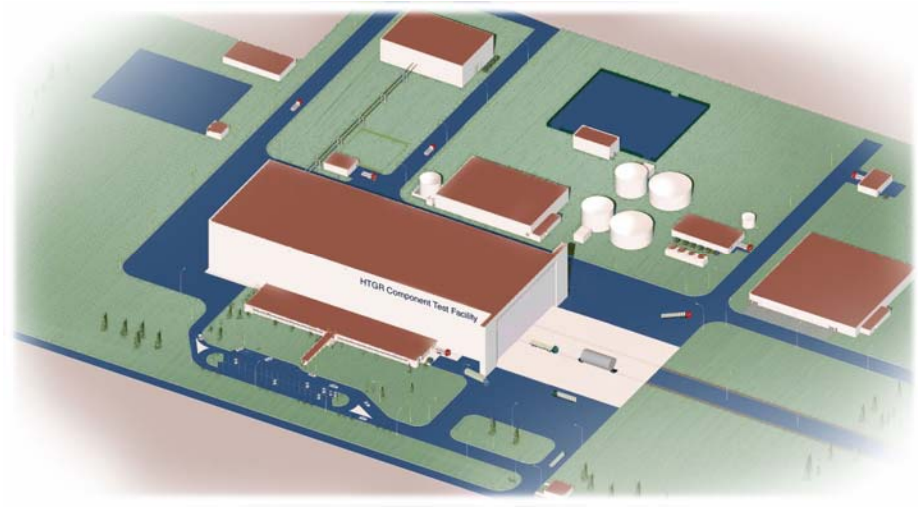
INL/EXT-08-14132

Facility Configuration Study of the High Temperature Gas-Cooled Reactor Component Test Facility

April 2008



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Idaho National Laboratory
Next Generation Nuclear Plant Project
Idaho Falls, Idaho 83415

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ABSTRACT

A test facility, referred to as the High Temperature Gas-Cooled Reactor Component Test Facility or CTF, will be sited at Idaho National Laboratory for the purposes of supporting development of high temperature gas thermal-hydraulic technologies (helium, helium-Nitrogen, CO_2, etc.) as applied in heat transport and heat transfer applications in High Temperature Gas-Cooled Reactors. Such applications include, but are not limited to: primary coolant; secondary coolant; intermediate, secondary, and tertiary heat transfer; and demonstration of processes requiring high temperatures such as hydrogen production. The facility will initially support completion of the Next Generation Nuclear Plant. It will secondarily 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 High Temperature Gas-Cooled Reactor technology.

This facility configuration study, which forms the basis for a cost estimate to support CTF scoping and planning, accomplishes the following objectives:

- Identifies preconceptual design requirements
- Develops test equipment schematics and layout
- Identifies space allocations for each of the facility functions, as required
- Develops a preliminary site layout including transportation, parking and support structures, and systems
- Identifies preliminary utility and support system needs
- Establishes preliminary electrical one-line drawings and schedule for development of power needs.

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ACRONYMS

AMB	active magnetic bearings
BMS	Building Management System
CFA	Central Facilities Area
CFD	computational fluid dynamics
CQL	component qualification loop
CTF	Component Test Facility
CTL	circulator testing loop
DSA	documented safety analysis
EIA	Electronic Industries Alliance
FMS	facility monitoring system
GA	General Atomics
H2PS	hydrogen production system
HICS	helium inventory and control system
HPS	helium purification system
HTE	high-temperature electrolysis
HTF	Hydrogen Test Loop Facility
HTGR	High Temperature Gas Reactor
HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and control
IBC	International Building Code
IEEE	Institute of Electrical and Electronics Engineers
IHX	intermediate heat exchangers
INL	Idaho National Laboratory
ITF	Integral Test Loop Facility
ITL	integrated test loop
LEED	Leadership in Energy and Environmental Design
LOFT	loss of fluid test
LTF	Loop Test Facility
NFPA	National Fire Protection Association
NGNP	Next Generation Nuclear Plant
NIST	National Institute of Standards and Technology
PA	public address
PDSA	preliminary documented safety analysis

RCCS	reactor cavity cooling system
SCADA	supervisory control and data acquisition
SE	SI electrolysis
SI	sulfur iodine
SPS	standby power system
TDL	technology development loop
TDL3	technology development loop 3
TIA	Telecommunications Industry Association
UL	Underwriter’s Laboratory
UPS	uninterruptible power supply
UV	ultra violet
V&V	verification and validation
VHTR	Very High Temperature Reactor
WEC	Westinghouse Electric Company

Facility Configuration Study of the High Temperature Gas-Cooled Reactor Component Test Facility

1. INTRODUCTION

The Next Generation Nuclear Plant (NGNP) project involves research, development, design, construction, and operation of a prototype nuclear plant intended for high-efficiency electricity production, high temperature process heat generation, and nuclear-assisted hydrogen production. As currently envisioned, NGNP will incorporate the Very High Temperature Reactor (VHTR) technology.

Recently a reference NGNP prototype concept was established based on the lowest risk technology development that will provide an economically competitive nuclear heat source and a hydrogen production capability. The reference NGNP conceptual schematic is shown in Figure 1. The concept includes a helium-cooled, graphite-moderated, thermal neutron spectrum reactor with a once-through fuel cycle. The reactor core will employ either the prismatic block or pebble bed fuel concept. Reactor outlet temperatures will be in the range of 850 to 950ºC, with future capabilities that could reach above 1,000ºC.

Advanced high-temperature reactor systems for power generation may be classified as direct and indirect cycles. Direct cycles use the reactor coolant, helium, as the working fluid of a gas turbine. As shown in Figure 1, the current NGNP concept uses an indirect cycle (judged the lowest risk option) having intermediate heat exchangers (IHXs) to transfer heat from the reactor primary loop to a secondary loop, which drives a gas turbine/electric generator, and to a hydrogen production facility. To isolate the nuclear and hydrogen production facilities from each other for safety reasons, this system includes a second intermediate heat transport loop. Hydrogen will be produced either by a thermo chemical process that splits water into hydrogen and oxygen (with sulfur-based processes being the primary candidates) or by thermally-assisted electrolysis of water.

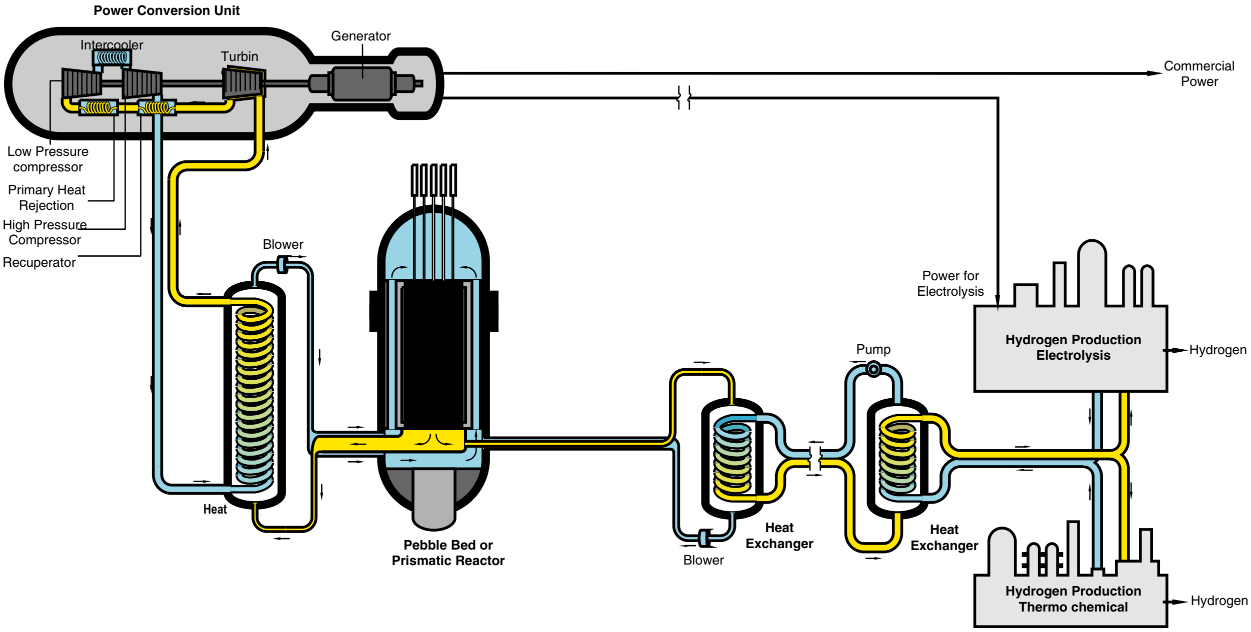


Figure 1. NGNP showing three IHXs.

The consensus among industrial power generation developers is that the IHX is the major challenge outside of the nuclear reactor. The power generation equipment, although customized for nonstandard working fluids, represents very low technical risk. The IHXs must handle the entire heat output from the reactor and do so at reactor outlet temperatures and pressures (950ºC and 7 MPa), which are at or near the operating limit for existing materials. Several IHX concepts are being considered, including a variety of innovative compact designs and more traditional tube-in-shell devices. Although bench-scale testing of prototypes is ongoing, pilot testing of an appropriate IHX module sized for VHTR conditions is not currently feasible. Accordingly, the IHX has been identified as a critical system component with both technological and programmatic risks.[1] Other VHTR components such as gas circulators (and their associated seals, bearings, etc.), high-temperature valves, recuperators, and high-temperature piping are also needed for the reactor system, but are not well tested at the necessary conditions. Even more fundamentally, materials for these components are not well tested at the temperatures, flow conditions, and impurity levels anticipated for the reactor system.

For these reasons, the NGNP Program Management Plan identifies the need for the design and construction of a reasonably large-scale, high-temperature gas test facility for component and materials testing. The specific high-level objectives identified for this facility are to:

- Provide a flexible, well-instrumented environment to evaluate IHX concepts and validate durability and efficiency, both for long-term and transient operating conditions
- Include the flexibility to evaluate the performance and durability of other critical high-temperature components, including circulators, valves, recuperators, piping, insulation, and instrumentation
- Provide a controlled-chemistry environment (pure and impure helium) for fundamental materials testing at VHTR temperature and flow conditions
- Include design flexibility such that the primary gas loop can be used as a heat source for future high-temperature demonstration facilities (e.g., a large-scale, high-temperature electrolysis [HTE] process loop).

2. MISSION NEED

A test facility, referred to as the High Temperature Gas-Cooled Reactor Component Test Facility or CTF, will be sited at Idaho National Laboratory (INL) for the purposes of supporting development of high temperature gas thermal-hydraulic technologies (helium, helium-Nitrogen, CO_2, etc.) as applied in heat transport and heat transfer applications in High Temperature Gas Reactors (HTGRs). Such applications include, but are not limited to: primary coolant; secondary coolant; intermediate, secondary, and tertiary heat transfer; and demonstration of processes requiring high temperatures such as hydrogen production. The facility will initially support completion of the NGNP. It will secondarily 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.

The CTF and its associated support facilities and systems will support:

- Qualification and testing of large-scale components in a high-temperature, high-pressure environment such as the:
    - 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 (V&V) collaboration
- Materials development and qualification
- Manufacturer and supplier evaluation and development.

An engineering-scale test facility is necessary to provide prototype testing and qualification of heat transfer system components (IHX, valves, hot gas duct, etc.), reactor internals, and hydrogen generation processing to mitigate the associated technical risks and to increase the technology readiness levels 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, if the NGNP was operated without prototype component testing and qualification, could result in incomplete risk mitigation with potential adverse impact on plant performance.

3. OBJECTIVES

The objectives of this study form the basis for a cost estimate to support facility scoping and planning. These objectives include:

- Identify preconceptual design requirements
- Develop test equipment schematics and layout
- Identify space allocations for each of the facility functions, as required
- Develop a preliminary site layout including transportation, parking and support structures, and systems
- Identify preliminary utility and support system needs
- Establish preliminary electrical one-line drawings and schedule for development of power needs.

4. BASIS OF CONCEPT

This section summarizes the assumptions that formed the basis for the CTF configuration concept. The preconceptual requirements for the CTF are presented in INL/EXT-08-14150 “NGNP CTF Functional and Operational Requirements.”

In addition to the CTF functions for high temperature component testing and qualification this facility as located near the Central Facilities Area (CFA) could function as an onsite fabrication facility for the construction of the NGNP or testing of components for other costumers. This will be further explored in follow-on conceptual design studies.

4.1 Facility Functions

The CTF Functional Diagram (see Figure 2) depicts the functions necessary to support the CTF mission. Below each of the seven high-level functions are the associated subfunctions.

4.2 Testing Requirements

4.2.1 IHX Component Tests

The high-temperature test loops should have the flexibility to test a range of IHX designs, configurations, operating conditions, and heat transport fluids. The heat transport fluids might have controlled levels of impurities in some tests. In the absence of a specific designs, the options proposed by the Westinghouse Electric Company (WEC), General Atomics (GA), and AREVA were used as the basis for evaluating the potential range of development requirements.

Mockups or scaled representative IHX concepts are required to be tested in operating conditions comparable to the anticipated NGNP conditions. The functionality for large-scale testing at representative conditions should not be excluded.

The main IHX tests to be conducted include:

- IHX performance verification testing, which could serve as empirical validation for thermal-hydraulic design methods and analysis.
- Life prediction and durability testing to evaluate design and fabrication methods, as well as data generated by material laboratories. Thermal-mechanical aspects of concepts should be evaluated during these tests, which typically include interface development.
- Seal tests on various sealing interfaces, as well as the influence on leak rates due to various process parameters.
- Flow-induced vibration tests and tests on IHX configurations and its associated piping, together with frequency spectra and sound pressure levels caused by different flow velocities.

4.2.2 Mixing Chamber Test

The high temperature test loops should be capable of performing various predefined tests on representative helium mixing chamber designs and configurations. The main mixing chamber tests to be conducted are:

- Performance verification test on a prototype mixing chamber
- Thermal cycling effects testing
- Nominal operating life of the mixing chamber (equivalent to NGNP plant life)

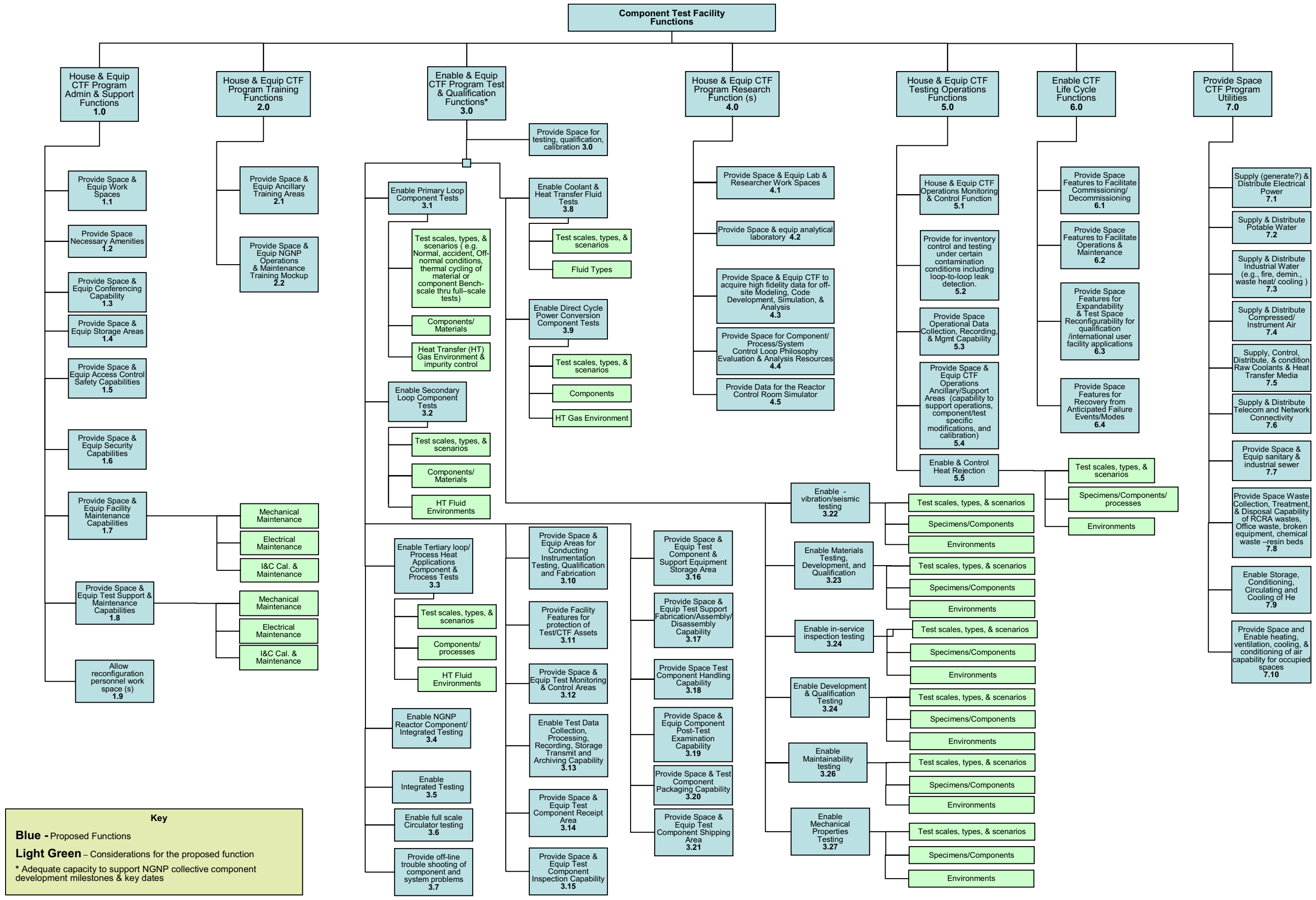


Figure 2. CTF Functional Diagram.

- Use of helium as the working fluid
- Different size fixed orifice testing for mixing gas.

4.2.3 High-Temperature Duct and Insulation Testing

The high temperature test loops should provide the capabilities to verify and experimentally validate the designs for high-temperature ducts and insulation to be used for fluid transport in both primary and secondary heat transfer loops. Experimental testing and validation will need to be performed on prototype samples, and emphasis needs to be placed on long-term validations.

4.2.4 Steam Generator Testing

The high temperature test loops should provide the capabilities to perform various tests on steam generator designs, which include:

- Acoustic response testing under different flow conditions, as well as flow induced vibrations due to various excitation mechanisms.
- Thermal and mechanical performance of steam generator-related insulation. Demonstration tests of certain design aspects in steam generators such as tube retention and wear protection devices, and the non-helical transition tubes. These tests would typically be used to determine the adequacy of existing designs and to evaluate new proposals.
- Seal-related tests to evaluate designs and validate performance-related criteria with varying parameters.
- Feed water-related tests that include aspects such as orifice performance verifications and design and manufacturing configurations.
- steam generator instrumentation related mock-up tests.
- steam generator performance tests to evaluate the heat transfer characteristics of certain regions.

4.2.5 Helium Circulator Testing

The high temperature test loops should provide for full-scale integrated tests of various circulator configurations that could assist in the verification of circulator component designs and adequacy of support systems. Typical tests will include:

- Circulator design verification tests
- Circulator performance empirical verification
- Circulator control system testing.

4.2.6 Valves Testing

The high temperature test loops should provide the capabilities to do performance and structural verification on high-temperature valves for maintenance and/or isolation, although design requirements are still to be determined.

4.2.7 Auxiliary Systems

The high temperature test loops should provide a complete array of auxiliary systems in support of the tests to be conducted. These auxiliary systems should include, but are not limited to:

- Helium purification system (HPS)

- Helium inventory and pressure control system
- Heat rejection systems (typically air-cooled condensers instrumented to enable full energy balances)
- Control instrumentation air system
- Water treatment plant.

4.2.8 Instrumentation and Control

The high temperature test loops must be used for instrumentation and control (I&C) philosophy development as well as adequacy verification for certain applications.

4.2.9 Other Helium Heat Exchanger Testing Requirements

The high-temperature test loops should be capable of performing various predefined tests on representative supporting component designs and configurations, including the shutdown HX. The main tests to be conducted in support of the shutdown heat exchanger are:

- Insulation verification tests
- Vibrational fretting wear and sliding wear of tube restraint
- Devices for bare tubes
- Instrumentation attachment test
- Bare tubes inspection methods and equipment
- Shroud seal test
- Acoustical response of the helical bare tube bundle
- Inlet flow and temperature distribution test
- Tube bundle local heat transfer and flow resistance characteristics.

4.2.10 General Testing Functions

The high temperature test loops should be used to address the following general testing functions:

- Provide data and measurements for verifying and validating thermal-fluid related software
- Provide control qualifications and develop associated program requirements
- Test and develop control room human factors
- Test the as yet to be defined specifics of hydrogen production.

4.2.11 Material Testing

Materials-related testing of IHXs and other heat transfer components should investigate a variety of metallic and nonmetallic materials-related phenomena including corrosion, erosion, and fouling of heat exchange surfaces. A primary issue for the 617 material that is presently specified for fabrication of the IHX is environmental degradation due to the long-term, high-temperature exposure to impure helium containing entrained particulate. The effects of alloy aging on mechanical properties and the evolution of deleterious microstructures must also be evaluated. The static and cyclic loads on the system must be simulated in a larger scale test program through the capability of imposing these forces on the samples. To address this issue, representative fault conditions and transient maneuvers will be simulated, during which potentially damaging stresses may be imposed on the heat exchanger test articles. These tests will provide data for qualifying materials used in the construction of the different heat exchanger designs and serve to validate finite element computer models against measured thermal and strain profiles. These validated software models will then provide the analysis tools necessary to cover a range of scenarios beyond those directly simulated.

Materials-related testing of non-heat transfer components such as valves, ducting, and insulation, will be performed to evaluate the life cycle performance at high temperatures (~950°C) and pressures (~9 MPa) during thermal cycling, exposure to mechanical and acoustic vibrations, particulate entrained in the gas stream, and under a variety of thermal and flow gradients. In addition to standard temperature, strain, and pressure measurements, advanced diagnostic capabilities, such as thermal imaging telemetry, in situ precision coordinate measurements for monitoring dimensional changes, and leak detection online at full-test conditions will be required to fully quality the components and materials being tested.

Testing of some of these materials and components may present some unique challenges. For example, the testing of materials used for valves will need to demonstrate adequate sealing while avoiding high-temperature galling. A known materials-related problem when operating valves at high temperature and contact pressure in a high-purity helium environment is the potential for “helium-welding”—a form of diffusion bonding between metal parts. The expected test format required to address this issue involves repetitive actuation of valves under hot flowing conditions with measurement of leakage and valve actuation torque. Some extended dwell periods at high temperature and pressure are also anticipated to fully qualify the materials and components.

A spectrum of extended endurance tests of material samples should also be planned to investigate material corrosion, fatigue, and creep. These tests can be performed on fabricated parts such as valve bodies, piping, and insulation sections, or on simple weld and braze coupons. Test stations located in the primary and secondary loops of the Loop Test Facility (LTF) will provide exposure to a range of gas velocities and temperatures. Tests requiring altered gas compositions, such as the addition of dust, water, or graphite particles, will most likely be performed in Test Station IHX 1.1 of technology development loop (TDL) 1, since this loop has a helium filtering and purification station immediately down stream of the test station to prevent the spread of contaminates.

Finally, testing of materials in the high temperature test loops may be needed to support the qualification of high temperature materials by the American Society of Mechanical Engineers Codes and Standards organization.

4.3 Space Allocation

4.3.1 CTF Space Allocation

Space allocation for the high temperature test loops were developed using 3-D models of assumed equipment sizes. The Administrative Office and High-Bay areas included the space allocation listed in Table 1.

5. FACILITY CONFIGURATION

The CTF complex will be designed to provide engineering-scale testing of a variety of NGNP components and systems and hydrogen production systems as well as allow for the V&V of software used in the design and analysis of advanced gas-cooled reactor systems. The CTF complex includes two major systems: high temperature test loops consisting of five component test loops, and the hydrogen test facility (HTF). The design will provide approximately 60 MWe of power to both the engineering-scale component test loops and HTF. Since the available power is limited to 60 MWe for each, the test loops and HTF will be operated and sequenced such that adequate power is available to meet the individual process needs throughout the testing program.

The high-temperature test loops consist of five component test loops for testing individual heat transfer components such as heat exchangers, high-temperature materials, and nonheat transfer components such as valves, piping, and insulation. All five will be high temperature (950°C max.) and pressure (9 MPa max.) helium loops with individual test stations for conducting the component test programs. Three of the loops will have a nominal heater power and helium flow of 4 MW(t) and 1.75 kg/s, respectively. A fourth, a component qualification loop (CQL), will be designed for testing larger components, including engineering-scale testing of components in the range proposed by AREVA, and would also allow for scaled testing of all or portions of the reactor vessel, core, and internal flow paths. It is envisioned that these latter tests would be approximately 1/4-scale experiments, primarily to provide test measurements for V&V of software used for designing and analyzing the NGNP. In particular, these experiments would be used for V&V of computational fluid dynamics (CFD) and system thermal-hydraulic analysis codes (i.e., RELAP5). This larger test loop will be connected to the other three loops with a valve and manifold system that will allow the CQL to utilize the heating, cooling and mass flow producing capabilities of the above three loops. The fifth component test loop will be the largest of the five loops and will be used for full-scale testing of helium circulators. This loop will have a test station for installation of the circulator(s), and a cooling system for removal of the energy delivered to the coolant by the circulator during testing. This includes power for the individual loop heaters, circulators, coolers, and any additions auxiliary support equipment.

The HTF will allow testing of scaled hydrogen production processes. The hydrogen production concepts being considered for testing in the HTF are: High -temperature Electrolysis, sulfur iodine (SI) thermal-chemical water splitting, and a hybrid SI electrolysis (SE) process.

The CTF Complex, which includes the processes in the CTF building, the Hydrogen Test Facility Process, support buildings and processes, and balance of plant, will demand less than 90 MWe. This will be the initial design goal of the CTF, since it will allow the greatest flexibility in support of the NGNP component and system testing programs. However, in the event that cost considerations or power availability prevent achieving this power level, an alternate option would be to design the CTF for a total power of 60 MW. This would allow testing of the hydrogen production process along with reduced power available for concurrent component loop and ITC testing. Alternatively, with the reduced power option, testing programs in the CTF could be coordinated by scheduling tests based on the power available. This reduced power option could, however, significantly reduce the CTF testing flexibility and extend testing schedules.

The following subsections provide more detailed information on each of the major CTF systems.

5.1 High Temperature Test Loop Configuration

The high temperature test loop concept includes three small, completely independent test facilities referred to as TDLs. Each of these loops can be connected to a common header in order to provide high-temperature helium at higher flow rates to a single large CQL. The CQL can then be used to qualify larger-scale components by using the combined mass flows and heat energies from the three TDLs. In addition to the TDLs and CQL, the high temperature test loop also includes a completely independent and separate full-scale circulator testing loop (CTL) that can test a 12.4 MW(t) circulator in a recirculation loop that includes a dedicated loop cooler.

Figure 3 (also shown as P-1 of Appendix A) presents a schematic of the high temperature test loop. The high temperature test loop will be the primary facility for testing individual components from small to full-scale. These components will be used to verify the performance of the final full-sized components that will be placed into the NGNP. As indicated above, the high temperature test loop consists of five separate loops: TDL 1, TDL 2, TDL 3, CQL, and CTL. Many components will be tested in a single loop as well as in combinations of loops. The main equipment and functions to be tested in the LTF are:

- IHX
- Mixing chambers
- steam generators
- High temperature valves
- Specific application high temperature instrumentation
- Industrial hydrogen components
- Helium circulators (1.75 kg/s and full size 159 kg/s)
- High temperature ducting and insulation
- Auxiliary systems
- System control
- Other heat exchanger equipment
- General functions.

During the next design phase of preconceptual design, draft Technology Development Road Maps will be prepared, including draft test plans for all NGNP components and systems tests.

The tests proposed for TDL loops 1, 2, 3, the CQL, and the CTL are as follows:

- TDL 1 Loop Tests:
    - IHX-W_1: WEC IHX Core A steady-state performance verification
    - IHX-W_2: WEC IHX Core B steady-state performance verification
    - IHX-W_3 WEC IHX Core A loss of secondary side pressure and flow performance verification
    - IHX-W_4: WEC IHX Core B loss of secondary side pressure and flow performance verification
    - IHX-G_1: GA IHX steady-state performance verification (maximum test core size)
    - MIX-W_1: Mixing chamber steady-state performance verification.
- TDL 2 Loop Tests:
    - IHX-A_1: AREVA IHX steady-state performance verification (maximum test core size).
- TDL 3 Loop Tests:
    - DIV-W_1: High-temperature ducts, valves, and insulation steady-state performance verification (small scale).

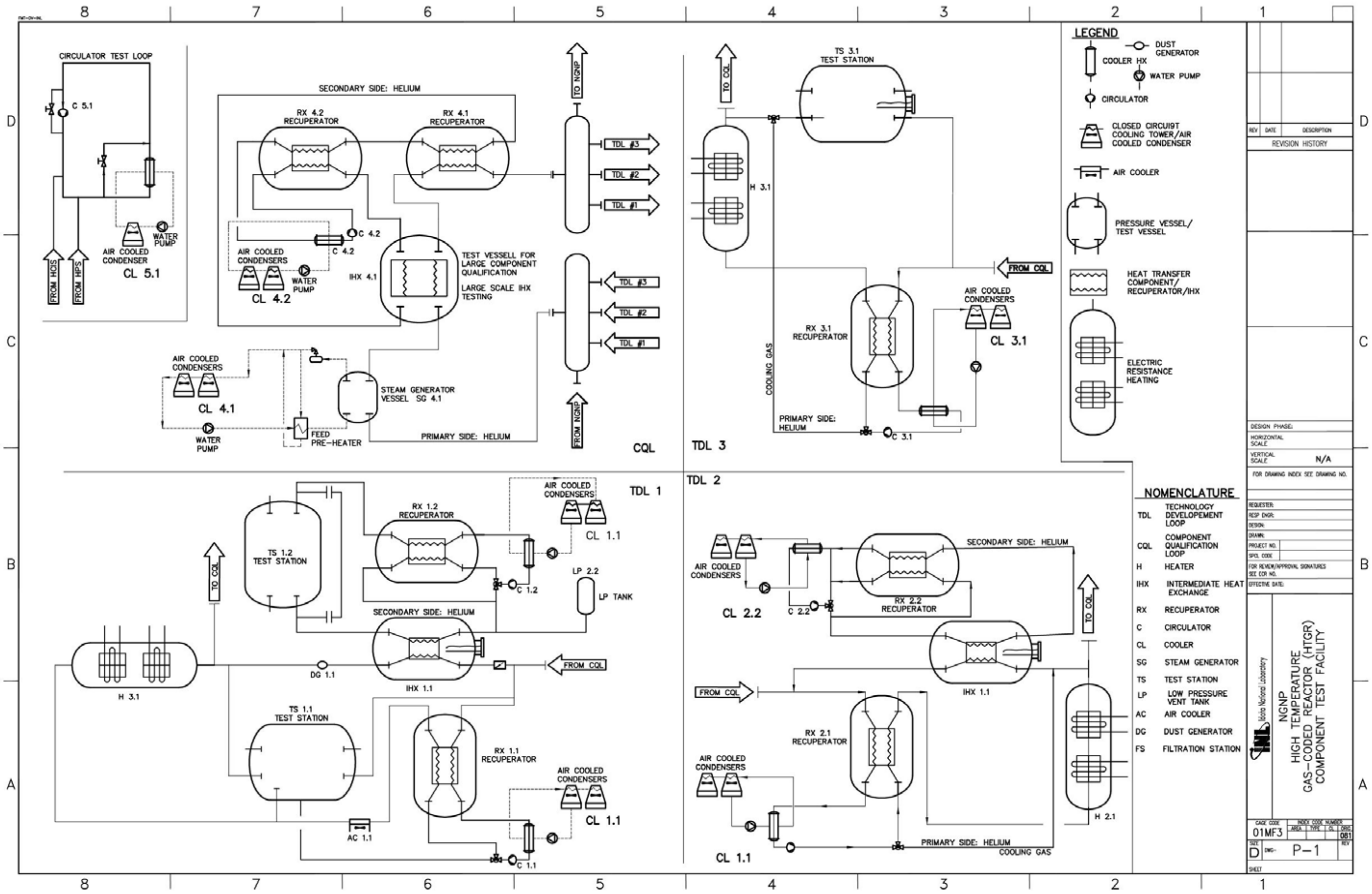


Figure 3. Schematic of the LTF.

- CQL Loop Tests:
  - IHX-G_2: GA IHX steady-state performance verification (maximum qualification core size).
  - IHX-A_2: AREVA IHX steady-state performance verification (maximum qualification core size)
  - DIV-W_2: High-temperature ducts, valves, and insulation steady-state performance verification (large scale)
  - steam generator-W_1: WEC steam generator steady-state performance verification.
- CTL Loop Tests:
  - CIR-W: WEC circulator steady-state performance verification
  - CIR-G: GA circulator steady-state performance verification
  - CIR-A: AREVA circulator steady-state performance verification.

5.1.1 TDL 1

TDL 1 consists of both a primary and a secondary loop as shown in Figure 4. Its main sizing requirements are based on the IHX test core requirements. Both primary and secondary loops are sized for only helium. Along with IHX testing, this small loop provides for testing of various components in a dedicated, fully instrumented test vessel in both the primary and secondary loop for temperatures up to 950ºC. It is also envisioned that TDL 1 will provide connection flanges for future testing of varying secondary loops contents such as liquid salt configurations interfacing with hydrogen production processes. This capability is provided in the form of extra connection points to the primary test vessel. Additional loop capabilities include testing of mixing chambers, by means of additional piping to the test station vessel in the primary circuit. The secondary side is connected via the IHX test core inside the IHX testing vessel.

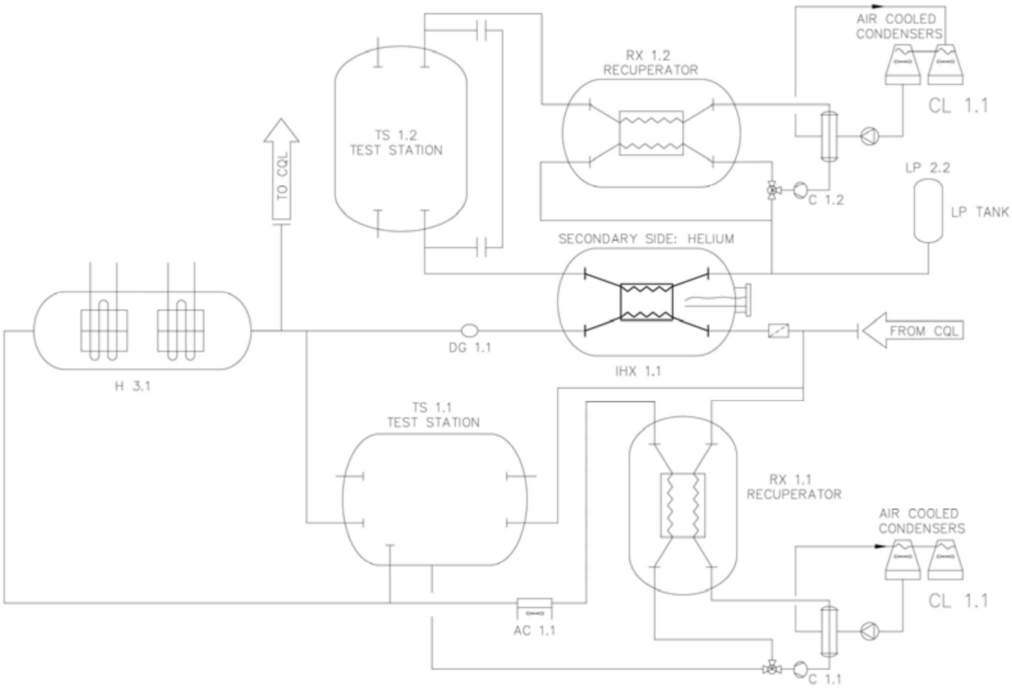


Figure 4. TDL 1.

The helium primary side of TDL 1 contains a 4 MW electric heater, a dust generator to supply contaminants to the helium working fluid, an IHX, a recuperator to increase efficiency, a cooler to cool the helium prior to entering a circulator, and the circulator. The helium then returns through the cool side of the recuperator to the heater. A test vessel is also placed in the primary system in parallel with the IHX test vessel. Helium can be diverted to this test vessel to test ancillary components. This test vessel is equipped to test helium mixers. The secondary side of TDL 1 is connected to the primary side by means of the IHX test core and is sized for helium alone. This loop is envisioned to have a test station vessel for possible expansion while the rest of the loop is very similar to the primary side. The only difference is a mixing valve at the circulator (see C1.2) outlet for controlling the IHX inlet temperature. The secondary side of the loop includes the cold leg of the IHX and consists of a test vessel, recuperator, helium cooler, and secondary helium circulator. Hot helium can also be diverted from the heater outlet to a manifold inlet in the CQL loop and returned from the CQL loop to the TDL 1 loop.

5.1.2 TDL 2

TDL 2 has a configuration similar to that of TDL 1, but differs in the fact that it does not provide a number of test station vessels as shown in Figure 5. This loop is mainly proposed for investigating different fluids such as He/N_2 mixtures in the secondary loop, while allowing for concurrent IHX testing by various vendors. The secondary loop is currently sized with helium, but further investigation is necessary to determine the suitability of one circulator for both helium and Ne N_2 mixtures. It is anticipated that a different circulator would be required for different fluids being tested.

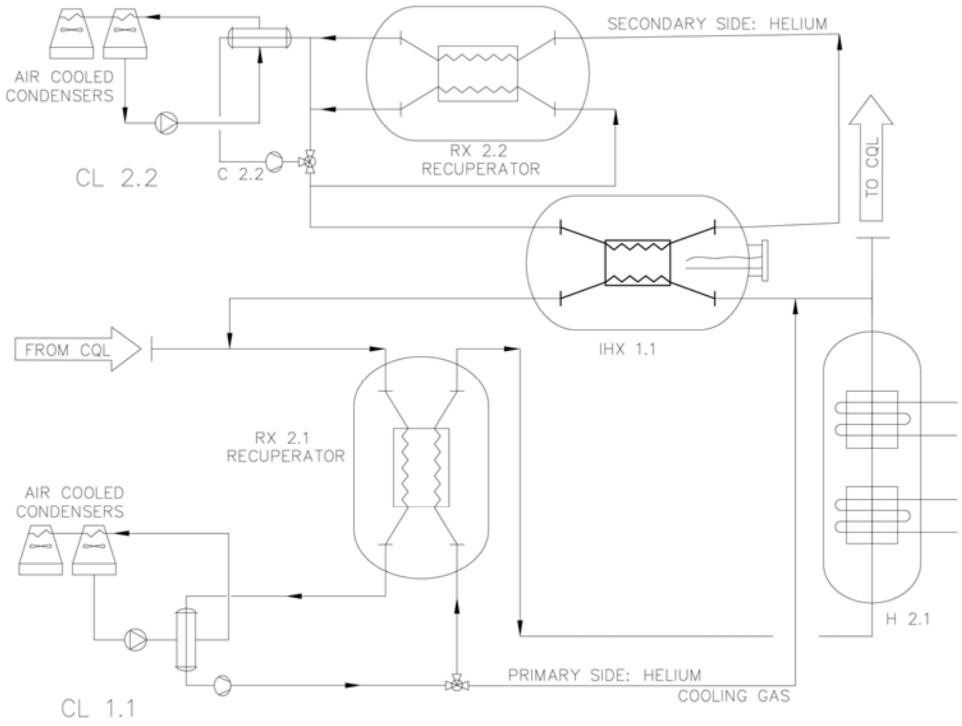


Figure 5. TDL 2.

The primary side of loop TDL 2 is similar to that of TDL 1 except that there is no parallel primary loop or test vessel. The secondary side in the cold leg of the IHX consists of a recuperator, helium cooler, and a secondary circulator. It is anticipated that the secondary side of TDL 2 will be used with either helium or other fluids under testing, such as He-N_2/CO_2 mixtures. Current sizing has been performed using helium, but further investigation is needed to determine the suitability of a single circulator. It is, anticipated, however, that different circulators will be used with different fluids, when tested. As with TDL 1, TDL 2 can divert hot helium from its 4 MW heater outlet to a manifold inlet in the CQL loop and return it from the CQL loop to the TDL 2 loop.

5.1.3 TDL 3

TDL 3 uses the basic building blocks as proposed in TDL 1, but with the sole purpose of providing a test station for non heat-transfer components such as valves, ducting, and insulation as shown if Figure 6. It also provides for the additional energy input when the loops are used concurrently and connected together in a common header. TDL 3 addresses the need for a separate facility due to long-term test requirements and the possibility of time constraint issues.

TDL 3 is similar to TDL 2 except that the IHX is replaced by a test vessel for nonheat transfer testing. There is no secondary loop in TDL 3. As with TDL 1 and TDL 2, TDL 3 can divert hot helium from its 4 MW heater outlet to a manifold inlet in the CQL loop and return it to the TDL 3 loop.

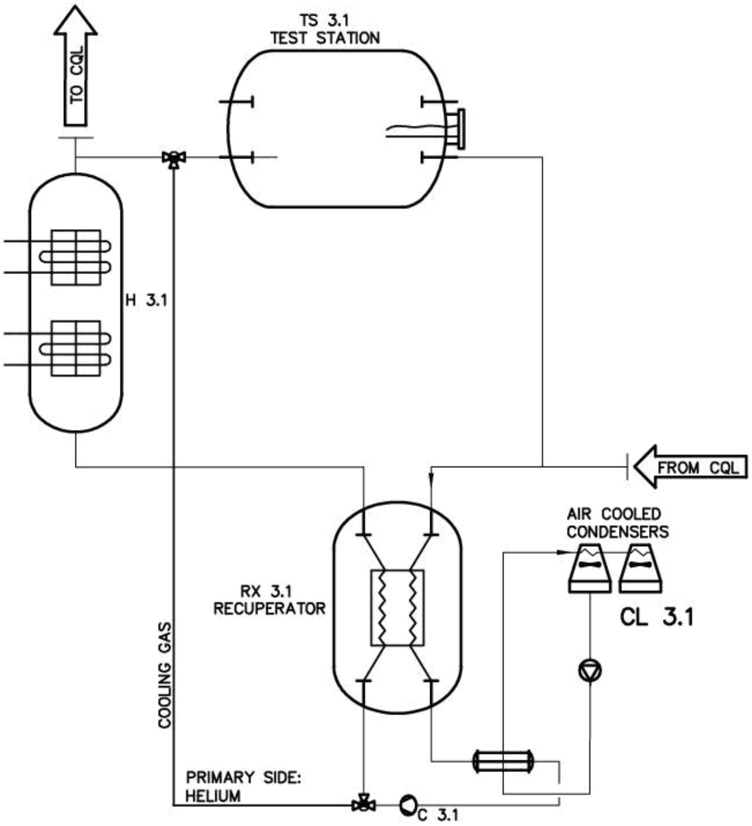


Figure 6. TDL 3.

5.1.4 CQL

The proposed CQL is a larger facility, which is required for larger-scale component qualification of up to 10 MW, as dictated by certain design data needs. It is anticipated that the primary circuit if the CQL will utilize the heating, cooling, and mass flow producing capabilities of the smaller facilities, TDL 1, 2, and 3, while incorporating a dedicated CQL secondary loop as shown in Figure 7. Typical tests on this facility include large-scale IHX cores of up to 10 MW, duct and insulation testing, and fully representative-size steam generators.

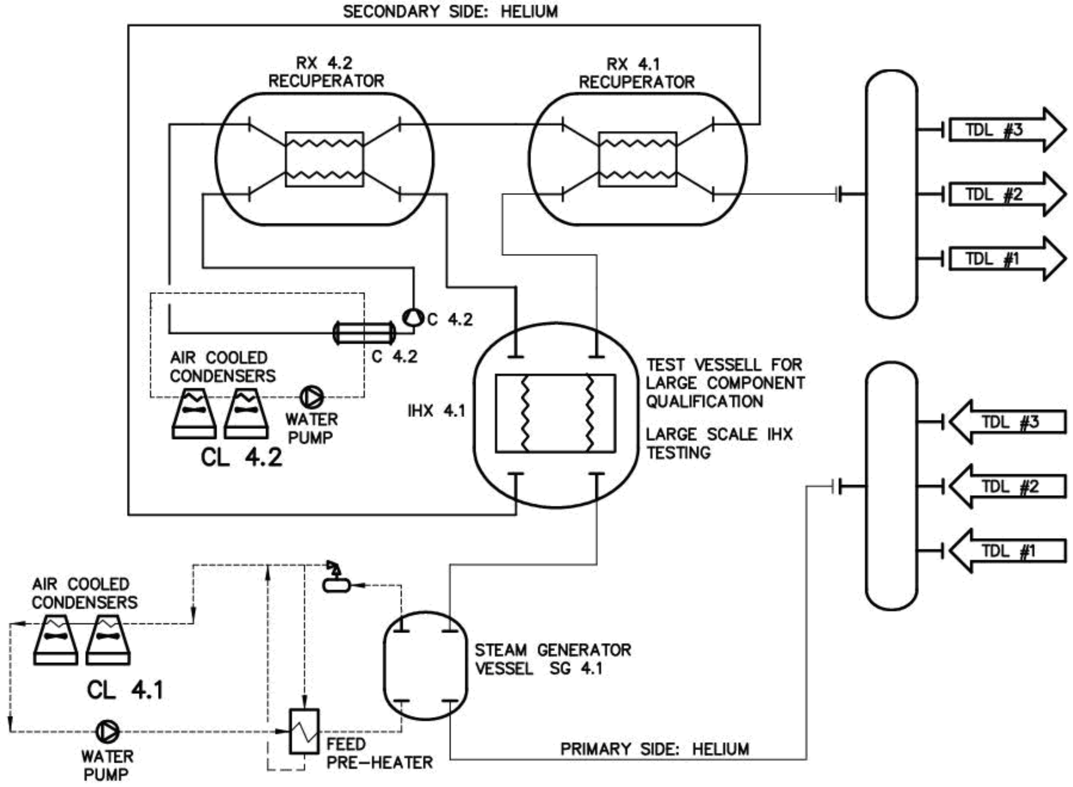


Figure 7. CQL.

The primary CQL receives its entire supply of heated helium from the electric heaters in TDLs 1, 2, and 3. It also returns the helium to these loops. The remainder of the primary CQL consists of a large steam generator test vessel (SG 4.1), a vessel for testing large components and large IHXs (IHX 4.1), and a primary system recuperator. The secondary side of the CQL is connected to the primary side by means of the IHX test core (in IHX 4.1) as well the recuperator (RX 4.1). The loop further consists of an additional recuperator (RX 4.2) as well as the normal cooler and circulator arrangement.

5.1.5 CTL

A proposed full-scale CTL will address full-scale testing requirements of different circulator designs. This separate loop is mainly proposed as part of the philosophy of not having two or more components under test in a single test configuration.

The final CTL is the full-size circulator loop shown in Figure 8. The loop components consist of a 12.4 MW circulator and a cooler to remove the heat transferred to the helium by the circulator.

5.2 Large-Scale Test Configuration

5.2.1 Large-Scale Duct Insulation and Isolation Valve Test Configuration

Figure 9 shows the CQL loop with insulated duct and isolation valve in the large component qualification test vessel. As indicated in Section 4.2.3, the LTF should provide the capabilities to verify and validate the designs for high-temperature ducts and insulation used for fluid transport in primary and secondary heat transfer loops. The LTF will also be used for performance and structural verification tests on high-temperature valves for control and/or isolation.

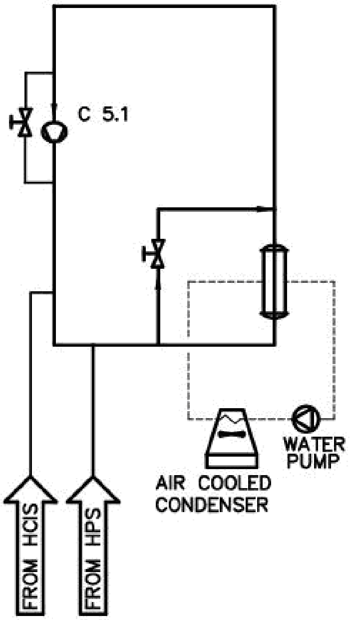


Figure 8. CTL.

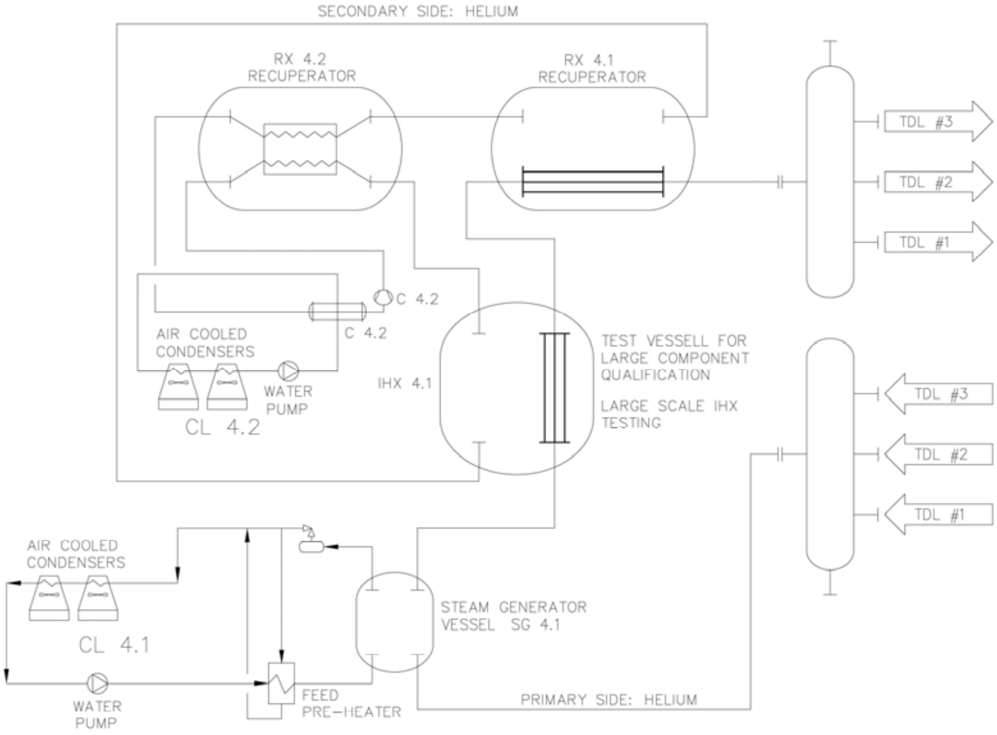


Figure 9. Insulated duct and isolation valve test.

Figure 10 shows the TDL 3 loop with a duct insulation, isolation, and valve test configuration in Vessel TS 3.1. This loop is equipped with a nonheat transfer test of the components.

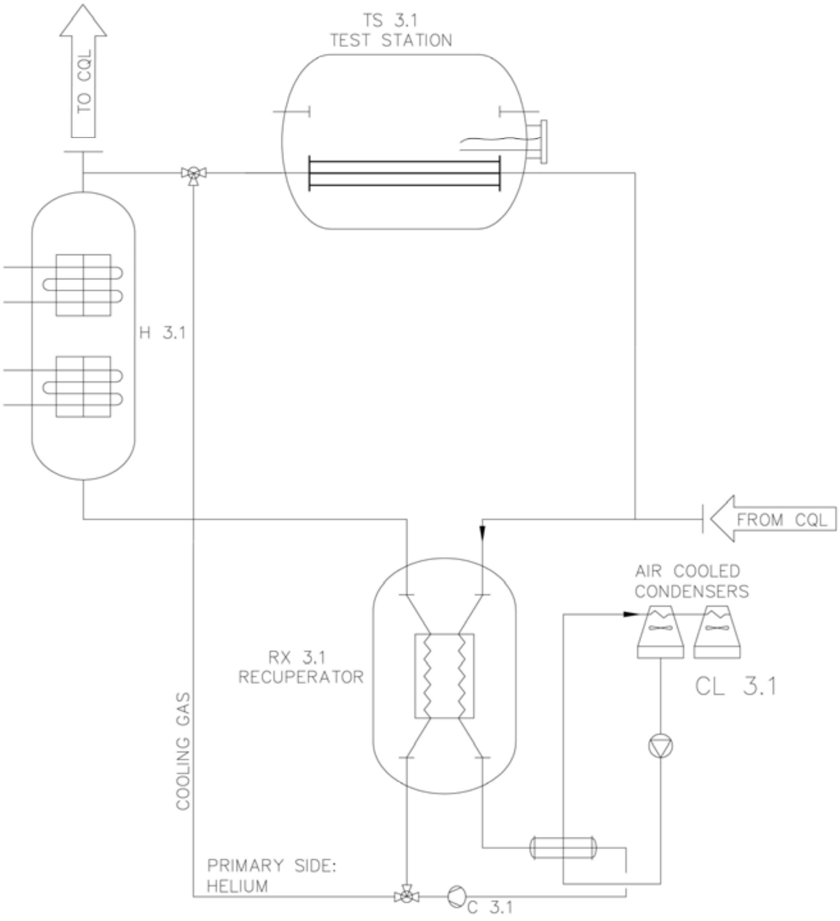


Figure 10. Insulated duct and valve test.

5.2.2 Large-Scale Steam Generator Test Configuration

Figure 11 shows the CQL loop with a steam generator to be tested in the steam generator vessel. This test vessel is equipped with air-cooled condensers to remove the heat from the secondary side of the steam generator. As indicated in Section 4.2.4, the steam generator tests will test the acoustic response under different flow conditions, flow induced vibrations, thermal and mechanical performance of steam generator insulation, tube retention and wear protection devices, nonhelical transition tubes, seal-related tests, feed water related tests, instrumentation tests, and evaluation of heat transfer characteristics of certain regions.

5.2.3 Large-Scale Circulator Test

The sole purpose of the CTL, shown in Figure 8, is to test full-scale helium circulators. There are many technical reasons why a full-scale circulator should be tested as opposed to a scaled version, and this is the reason for this full-scale test loop. This loop will be able to test various circulator configurations. As indicated in Section 4.2.5, the large-scale circulator test will assist in the verification of circulator component designs and the adequacy of support systems, verify circulator designs, verify circulator performance empirical data, and aid in circulator control system testing.

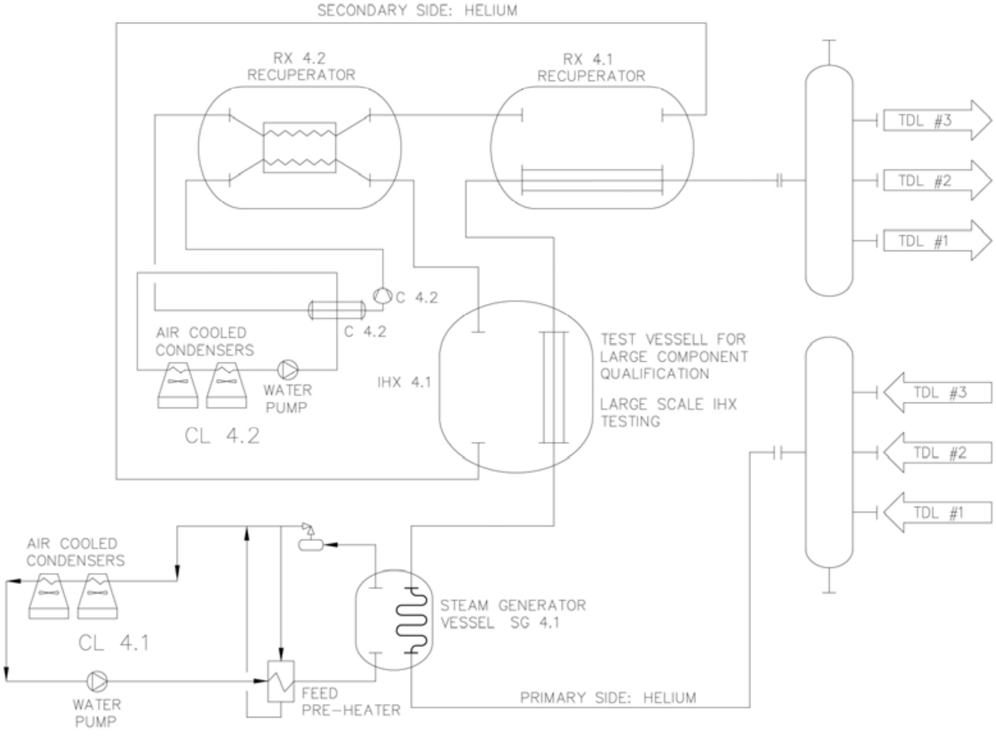


Figure 11. Steam generator test with auxiliary cooling system.

5.3 Future Expansion of CQL for Large-Scale Testing and Qualification

As indicated earlier, the phased expansion of the CQL for larger scale component testing and qualification is an option for future consideration. This larger loop could include its own power supply, circulator and secondary cooling system(s) that would allow a broader range of large scale testing options. The CQL is currently designed for a nominal flow capacity of 5.25 kg/s by combining the flow capacities of the three TDL loops. The advantage of this concept is that it eliminates the need for additional heaters and helium compressors by utilizing a manifold system to divert all or a portion of the flow from the three TDLs to the CQL. The current power and flow capacity of the CQL appears to meet most component qualification testing needs of WEC as outlined in their February NGNP CTF report. The disadvantages of the CQL concept is that tests cannot be run concurrently in the TDL loops while the CQL is operating, and the test facility flow and power capabilities fall short of those proposed by AREVA (Report TDR-3000256-000). Also, while a detailed scaling study has not been performed, preliminary INL estimates of the flow and power requirements for a ¼-scale model of the NGNP reactor and its internals (to be used for software V&V testing), suggest that the current capability of the CQL may not be adequate for the full range of potential tests envisioned.

For the above reasons, a larger component testing and qualification loop is being considered as a future expansion to or replacement for the current CQL loop design. The increased size of this loop should meet the power and flow needs of the ¼-scale model for simulating the NGNP reactor and its internals and also address the AREVA large-scale component testing needs.

To meet the large component testing requirements proposed by AREVA, the minimum flow for a future expansion of the CQL would be approximately 10 kg/s, and the power requirement would be 30

MW (Report TDR-3000256-000). As discussed earlier, it is also envisioned that this larger loop could be used for large-scaled mockup testing of all or portions of the reactor vessel, core and internal flow paths. The primary intent of these tests would be to provide data for V&V of software use for design and analysis of the NGNP. In particular, it will be used for V&V of computational fluid dynamics (CFD) and system thermal-hydraulic analysis codes (i.e., RELAP5).

To arrive at the power requirement for the ¼-scale reactor model, it was assumed that the focus of the experimental program would be on integral system conditions when the NGNP reactor was operating at decay power levels (conservatively 5% of full power). At 1/4-scale, the integral test facility power would be P = 600 MW x 0.25 x 0.05 = 7.5 MW. To allow flexibility to operate at higher than decay power, the power level for the mockup tests was set at 20 MW(t). Assuming that the primarily focus of the integral testing is on the prismatic core design (AREVA and GA); the required total flow is 320 kg/s x 20/600 = 10.7 kg/s. The Westinghouse design would have a lower flow rate since the temperature rise across the core is higher.

Although the facility would be designed for ¼-scale experiments, the actual dimensions of the facility will not necessarily be a quarter of the diameter and/or height of the NGNP since scaling laws can be applied to develop actual facility dimensions similar to the way the Semiscale and LOFT facilities were designed.

The table below summarizes the power, flow and temperature requirements for the AREVA large-component tests (both primary and secondary) and the INL ¼-scale vessel model tests. The last column of the table provides the recommending power and flow requirements for the proposed future expansion to the CQL to meet the needs of the two testing programs.

Table 1 summarizes the power, flow, and temperature requirements for the AREVA large-component tests (both primary and secondary) and the INL 1/4-scale vessel model tests. The last column of the table recommends power and flow requirements for the proposed Integrated Test to meet the needs of both testing programs.

Table 1. Power requirements.

	AREVA Large-Component Tests	**INL 1/4-Scale Vessel Tests**	**Recommended ITF Requirements**
Heater power requirements (MW)	25–30 MW	20 MW	30 MW
Primary system flow rate (kg/s)	10.0	10.7	15.0
Primary system temperature (°C)	850–1000	950	950
Primary system pressure (MPa)	4.0–7.0	9.0	9.0
Secondary system flow rate (kg/s)	10.0	N/A	10.0
Secondary system temperature (°C)	950	N/A	900
Secondary system pressure (MPa)	3.5–7.5	N/A	3.5–7.5

5.3.1 Integrated Test Size and Facility Layout

The area required for construction of the Integrated Test is estimated to be about 36,000 ft^2. This area should satisfy the space needs the integrated test article, as well as the primary and secondary systems required for the scaled AREVA large- scale component tests. The estimated pipe diameter for the circulating helium loop flows is about 0.4 m (1.3 ft) for an assumed helium flow velocity of 30 m/s. The ITC control room, data acquisition systems, helium supply and purification systems, and any other required support systems will be located outside of this area as defined in the overall layout for the CTF facility.

5.3.2 Anticipated Tests

The Integrated Test is intended for large-scale testing of all or portions of the NGNP reactor vessel, core and internal flow paths. A full scale mockup of the vessel and Reactor Cavity Cooling System (RCCS) probably represents the most complete system that would be tested in the Integrated Test. In this configuration, NGNP reactor decay power would be simulated with electrically heated core components, and heat would be removed through the simulated RCCS to evaluate reactor cooldown during both pressurized and unpressurized loss-of-flow events (commonly referred to as conduction cooldown transients). A variety of additional tests could also be performed involving primary circulator coast down and restart to evaluate coolant flow distributions within the reactor vessel and core region.

In addition, a variety of tests would be performed on portions of the system, including mockups of the core, upper plenum, lower plenum, and vessel inlet and exit nozzles to evaluate temperature, pressure and flow distributions. Fluid behavior and conditions in these regions would then be used for V&V of CFD and system analysis codes that will be used for design and analysis of NGNP and future advanced gas reactor concepts. The scaling of all of these potential component or system tests may vary, but the ultimate experiment design will be constrained by the power and flow requirements defined above.

Finally, the Integrated Test would be designed to test the large-scale components at 1/3- to 1/5-scale, including valves, circulators and the AREVA IHX design. In addition, provisions will be included to include the later addition of a steam loop for large-scale testing of steam generator designs.

5.3.3 Instrumentation and Support Systems

It is anticipated that component tests performed in the Integrated Test will be highly instrumented since the primary purpose of the tests will be to obtain detailed information on steady-state and transient fluid flow conditions for V&V of software models. Therefore, it is possible that experiments performed in Integrated Test could require several thousand measurements. Although each experiment developers will be responsible for the instrumentation of their own test article, the CTF will still be responsible for providing adequate systems for the acquisition, processing and storage of all anticipated data needs. This includes experimental data as well as data for the control and safety functions of the experiments being performed.

5.3.4 Auxiliary Systems

The principal auxiliary systems supporting the Integrated Test are the HPS and the cooling system utilized to reject waste heat from the primary and secondary loops. The helium purification system, which is discussed elsewhere in this SOW, will be capable of removing dust and other contaminates from the circulating systems and providing helium at a purity level consistent with that required for NGNP operation. .

5.4 Major High Temperature Test Loop Auxiliary Systems

5.4.1 Cooler-TDL Primary Side

The cooler is used to cool the helium prior to entering the circulator. The circulator inlet temperature is conservatively limited to 80°C. The maximum helium temperature at the inlet to the cooler, without gas bypass from the surge control valve, is approximately 260°C. The required maximum duty of the cooler at a nominal flow rate of 1.75 kg/s is 1.6 MW. It is suggested that either an air cooler or shell-and-tube cooler be used for this application. An air cooler requires a variable speed drive to control the outlet temperature. The shell-and-tube heat exchanger performs better when sudden temperature transients are present due the thermal inertia of cooler and coolant. If a shell-and-tube unit is used, it is recommended that a water and ethylene glycol mixture be used. The use of a mixture of water and ethylene glycol would possibly require a closed circuit cooling tower. A maximum coolant flow rate of 20 to 25 kg/s is required to keep the water temperature below 50°C at the cooler outlet. The outlet temperature of the helium can then be regulated by using a coolant bypass and circulating loop.

5.4.2 Cooler-TDL Secondary Side

The secondary side loop of the TDL requires fluid cooling from 460 to 80°C. The high inlet temperature requires the use of an air cooled helium cooler. The required maximum duty of the cooler at a nominal flow rate of 1.15 kg/s is 2.5 MW. A first order estimate of the size of the cooler is approximately 4.0 × 4.0 × 0.5 m. The cooler uses four axial flow fans to supply the required air-flow rate of 60 kg/s.

5.4.3 Cooler-CQL Secondary Side

The secondary side circulator inlet temperature is also conservatively limited to 80°C. The maximum helium temperature at the inlet to the cooler, without gas bypass from the surge control valve, is approximately 185°C. The required maximum duty of the cooler at a nominal flow rate of 5.25 kg/s is 2.6 MW. A shell-and-tube cooler is recommended for this application, also with a water and ethylene glycol mixture as secondary coolant. A maximum coolant flow rate of 25 to 30 kg/s is required to keep the water temperature below 50°C at the cooler outlet.

An auxiliary cooling system is required for each TDL to supply cool, treated water to the helium coolers, if shell and tube coolers are used. The operation and reliability of the auxiliary cooling system is of utmost importance to avoid damage to the helium circulators. The auxiliary cooling system consists out of the cooling tower, water treatment and make up system, cooling pumps, and interconnecting pipes.

5.5 HTF

The HTF will be designed to allow testing of the three principal hydrogen production processes under consideration by the NGNP Program. These hydrogen production processes are: HTE, SI thermochemical water splitting, and a hybrid SE process.

To accomplish these tests, adequate space will be provided on the CTF site plan to accommodate each of the concepts under consideration. The CTF Program will provide the required power for separate testing of individual hydrogen production processes and supply required feedstock and process materials. The CTF Program will provide major auxiliary support equipment: heating, ventilation, and air conditioning (HVAC), heating, ventilation, and air conditioning water conditioning systems, and electrical power. However, the system supplier is expected to provide all equipment required to test and demonstrate their complete hydrogen production system (H2PS).

The following sections discuss the HTF power requirements, site layout, and auxiliary equipment needs for the HTF testing program.

5.5.1 Power Requirements

The HTF will accommodate testing of each of these designs at the same scale proposed for testing with NGNP. The current requirement is that the hydrogen production plants will be designed to use up to 50 MW of thermal power from the NGNP reactor. However, because each of these concepts requires different ratios of thermal-to-electrical power to produce equivalent amounts of hydrogen, the electrical and thermal power requirements for the three concepts will differ.

The approximate HTF thermal and electrical power requirements for the HTE and SI hydrogen production concepts are presented in Figure 12. The HTE process, shown at the top of the figure, requires primarily electrical power for the production of hydrogen, and only needs about 10% of the available reactor thermal power for process heat. Approximately 45 MW of the available reactor power is delivered to the power conversion system to produce the required electrical power for the HTE process. For an assumed power conversion thermal efficiency of 50% (e.g., for a direct Brayton cycle gas turbine power conversion system), the resulting electric power delivered to the HTE process is 22.5 MW. The remaining 5 MW of the total 50 MW of reactor power is then delivered to the HTE process as high-temperature process heat for a total of 27.5 MW of combined electrical and thermal power. This total power, shown in the dashed box in the top portion of the Figure 12, is the total power that would be provided by the HTF to the HTE process to produce approximately 12 kg/min of hydrogen.

On the other hand, the SI process shown at the bottom of Figure 12 requires primarily thermal process heat from the reactor. It is therefore assumed that approximately 90% of the available reactor thermal power (45 MW) is delivered directly to the SI process as thermal heat. The remaining 5 MW is delivered to the power conversion system, which, at 50% efficiency, provides 2.5 MW of electricity to the SI hydrogen production process. Therefore, the total combined electrical and thermal power that the HTF facility must deliver to the SI process (shown in the dashed box at the bottom of Figure 12) is 47.5 MW.

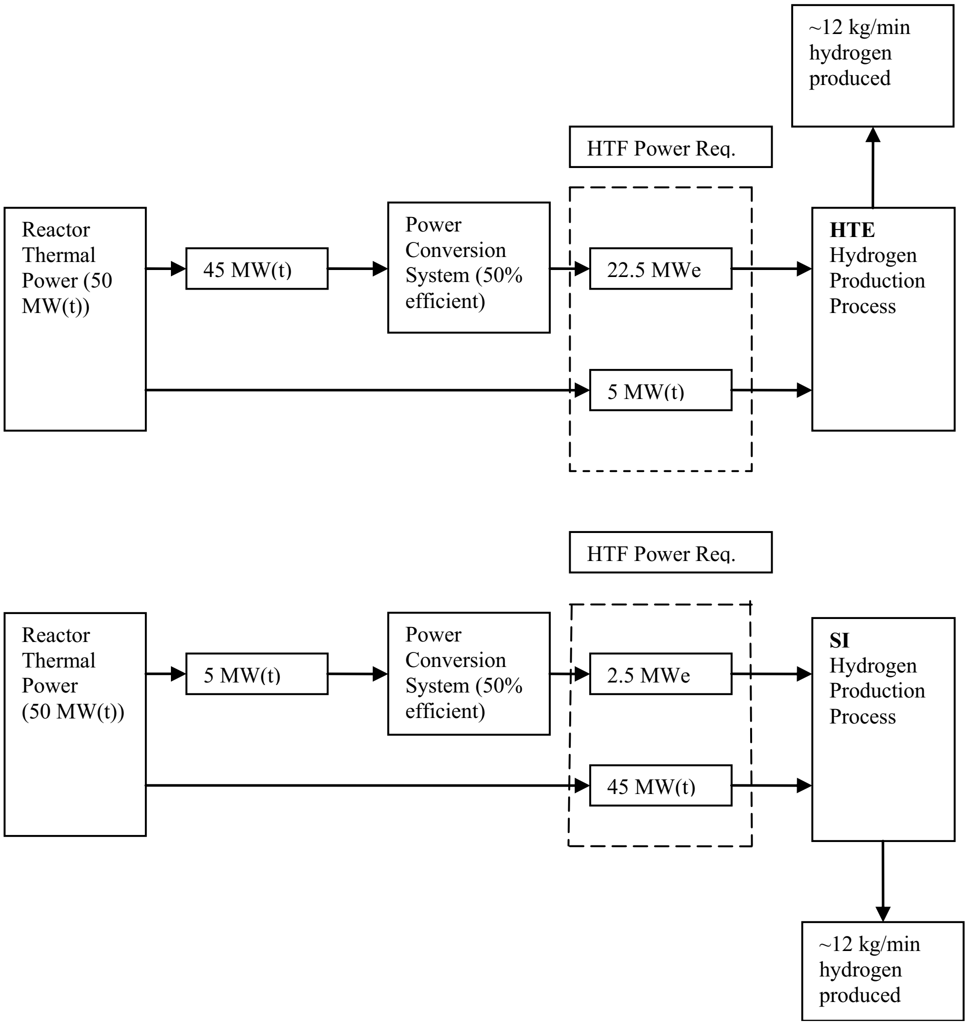


Figure 12. Comparison of HTE and SI hydrogen production power requirements.

The total combined electrical and thermal power for the SI hydrogen production process is therefore higher than that required by the HTE process for equivalent hydrogen production rates (~12 kg/min).

The power requirements summarized in Figure 12 assume that each of the hydrogen production processes use the full 50 MW of thermal power available from the NGNP reactor. However, the decision to use 50 MW(t) of NGNP reactor power to drive the hydrogen production processes was primarily based on the need to test the SI and SE processes at a sufficient size to demonstrate the viability of full-scale hydrogen production. Because of the modular nature of the HTE process, it is generally believed that the HTE process can be tested at a lower power (5 MWe) to adequately address the viability and performance of a large-scale HTE hydrogen production process. The HTF total power requirement was therefore set at 50 MW to ensure the testing requirements of all three hydrogen production concepts are met and to meet the higher total anticipated power requirements of the SI and SE processes. This allows more than enough power to test the HTE process at 5 MWe, and the option to increase the size of the HTE unit at a later date if necessary or desired.

Current plans to meet the total power requirements of the CTF are to build a new 100 MVA power substation at INL. Although other methods of meeting the high-temperature process heat requirements of the test facilities were investigated, the quantities of liquid fuel required and the absence of a natural gas pipeline to the site eliminated these options.

The need to use electrical power to supply both heat and electricity does have an impact on the total power requirement. For example, the SI process described above requires 45 MW of thermal power and 2.5 MW of electrical power. If the HTE hydrogen production process is tested at 5 MW electrical power, the process heat requirement would only be about 500 kW(t). If natural gas were available, both hydrogen production processes could be tested using 5 MW of electrical power and 45 MW of process heat from industrial natural gas burners. This could reduce the required total electrical power by 40 MW, and significantly reduce the power requirements.

5.5.2 Site Layout and Preparation

The site plan for testing the hydrogen production processes is shown on the plot plan in Appendix A. Anticipating that the SI process will have the largest footprint of the three concepts under consideration, that concept was used in developing the general configuration and size of the testing area for the three hydrogen production processes. It is assumed that each process will be tested separately and time will be provided between testing programs to allow the disassembly of one process and the assembly of the next process to be tested.

Because the SI process is used in developing the site layout, the following gives a brief description of the SI process, followed by a discussion of the auxiliary and support system requirements for each of the hydrogen production processes. A simplified SI process flow schematic is shown in Figure 13.

The sulfur-iodine cycle consists of three chemical reactions. In the first reaction, known as the Bunsen Reaction, sulfur dioxide (SO_2), iodine (I_2), and water (H_2O) react at low temperatures (approximately 120°C) to form sulfuric acid (H_2SO_4) and hydrogen iodide (HI). In the second reaction, H_2SO_4 is decomposed over a catalyst at 850°C to form SO_2, H_2O, and oxygen (O_2). In the third reaction, HI is decomposed into hydrogen (H_2) and I_2 at approximately 300°C. These reactions are shown below.

$$\mathrm{SO_2 + I_2 + 2\,H_2O \rightarrow H_2SO_4 + 2\,HI} \qquad \textit{low temperature reaction}$$

$$\mathrm{H_2SO_4 \rightarrow SO_2 + H_2O + \tfrac{1}{2}O_2} \qquad \textit{decomposition at } 850\ ^{\circ}\mathrm{C}$$

$$\mathrm{2\,HI \rightarrow H_2 + I_2} \qquad \textit{decomposition at} \approx 300\ ^{\circ}\mathrm{C}$$

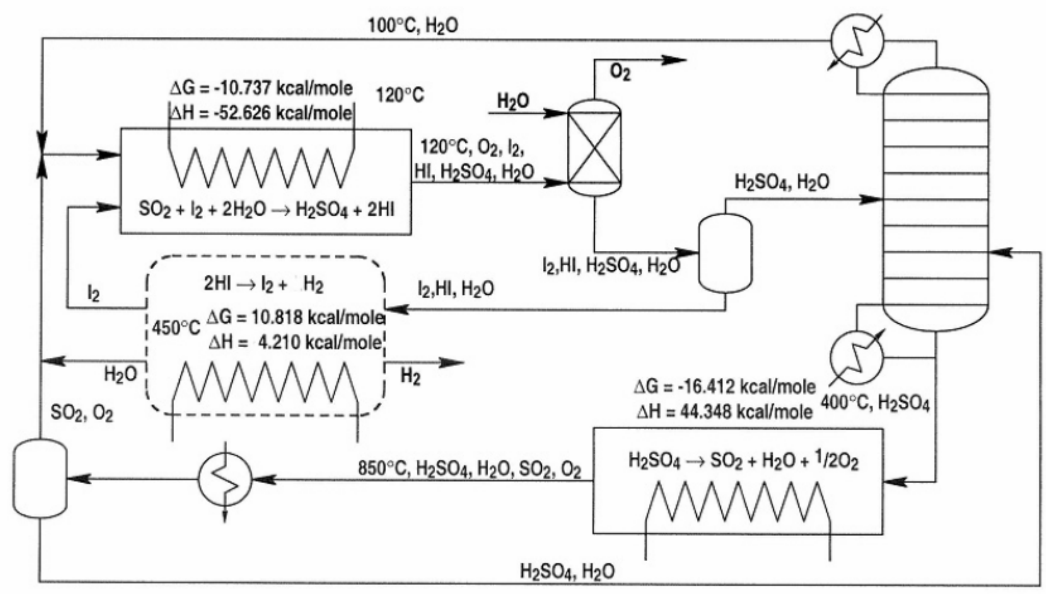


Figure 13. Simplified SI process flow schematic.

When the entire process reaches steady state, the only inputs are H_2O to the Bunsen Reaction (first reaction) and high-temperature thermal energy to the second and third reactions. The outputs are the hydrogen product gas from the decomposition of HI (third reaction) and oxygen (O_2) from the decomposition of H_2SO_4 (second reaction). The chemicals H_2SO_4, SO_2, HI, and I_2 are recycled in the process by formation and decomposition mechanisms. The SI thermo chemical process consists of three separate chemical processing sections and process support systems (corresponding to the three reactions described above). The three processing units are main solution reaction, sulfuric acid concentration and decomposition, and hydrogen iodide (HI) decomposition. Process flow sheets along with fluid conditions and equipment summaries for each of these sections for a large hydrogen production plant driven by four 600 MW(t) HTGRs are available in GA report GA-A24285, June 2003.

The SI plant that will be driven by the NGNP is much smaller than the full-size plant described in the above GA report, and a detailed design for this plant has not been developed. The approximate size and configuration of the footprint for the HTF was therefore determined by scaling from the GA preconceptual design for a large hydrogen production plant driven by four 600 MW(t) HTGRs. The hydrogen production plant size was estimated to be approximately 1,050 × 300 ft for a total area of 315,000 ft^2 based on the full-sized plant design described in GA Report GA-A25401. Multiplying this area by the respective thermal powers of the two facilities—50 MW/2400 MW—gives a required area for the HTF of 6,563 ft^2. This footprint size was increased to approximately 20,000 ft^2 to allow special monitoring and maintenance needs, access requirements, and pipe spacing factors.

The space requirements for the electrolysis process were also estimated in anticipation that the HTE process will be the first design to be tested in the HTF. Table 2 summarizes the estimated floor space for the HTE process, which was scaled up from the 500 kWe pilot scale HTE concept developed by INL. Because of the smaller size, number of components, and the modular nature of the design of the HTE process, which is currently planned to be run at 5 MWe power, the estimated space requirement for this concept is approximately 4,400 ft^2, well within the available space allotted for the hydrogen test facility.

Table 2. Space requirements for 5 MW HTE facility.

Equipment	Floor Area (ft^2)
Electrolysis Stack	365
Water Conditioning Equipment	600
High Pressure Make-up Water Pump	100
Low Temperature H_2/Water heat exchanger	60
Low Temperature Process Heat Input heat exchanger	60
High Temperature O_2/Steam heat exchanger	60
High Temperature H_2/Steam heat exchanger	60
High Temperature Process Heat Input heat exchanger	60
Condensate Separator	100
Catalytic Oxidizer	mounted above
Access/Clearance/Piping Space Factor	3x

5.5.3 Plant Auxiliary and Support Systems

Many of the auxiliary and support systems required for each of the hydrogen production processes will be supplied by the CTF Program. These systems include required electrical and thermal power supply systems to drive the processes; appropriate systems for data acquisition, storage, and display; process control and safety systems; and adequate conditioned water feedstock to drive the processes. Other process specific systems and materials, including chemical materials, process delivery, and control systems, will be supplied by the process developers. All components, systems, and instrumentation associated with the actual hydrogen product process itself will also be supplied by the process developer performing the tests in CTF. This will require coordination between the hydrogen system developers and the CTF Program to ensure that adequate data acquisition and support systems are available to meet the needs of the developers.

Process control and safety systems will be unique to each of the processes being tested. However, some general requirements, identified in INL/EXT-06-11232, Rev 1, that apply to one or more of the three hydrogen production processes are discussed briefly below.

Control Systems

Control systems will be needed to monitor and maintain system temperatures, pressures, and flow rates at desired levels. Their design should incorporate audible and visual alarms to allow operator intervention or to take automatic action if measurements indicate that the process is operating outside of normal operating parameters. The alarm indicators should signal both locally and at the hydrogen production plant’s central control station. Control systems should be integrated so that the responses of individual controllers are synchronized with the responses of other system controllers.

Process vessels, pipes, heat exchangers, and other equipment in the hydrogen generation process all operate at different temperatures. Temperature monitoring and control will be needed to maintain the proper operating temperature for each process unit. Temperatures are monitored by temperature sensors such as thermocouples and thermistors, and are controlled by control units that alter the input and output of flow rates and power that direct heating/cooling units to maintain temperature set points. Optimizing the placement of temperature sensors will minimize the number required by temperature controllers. Depending on the design of the temperature controller, the temperature of a single component may be monitored and controlled or the results from many temperature sensors may be integrated and analyzed in order to control the temperature of a whole process unit, or even influence the overall operation of the hydrogen production plant.

Material transport between process units requires flow monitoring and control to keep the process steps operating at optimum conditions. Depending on the process, flow monitoring and control can vary in design and function. Similar to temperature control, flow monitoring sensors such as mass flow meters and velocimeters provide input to one or more flow controllers. Flow controllers influence the flow rates by changing the position of flow control valves and/or adjusting the work rates of pumps or compressors. Flow control can be local and focused on only one component, or the signals from many flow sensors can be integrated to simultaneously control the flow rates in many components or locations.

Temperature and flow control is often sufficient to maintain system pressures, but additional pressure protection may be required in some cases as realized through pressure control. A pressure controller will receive input from one or more pressure sensors in a unit or flow stream and motivate a response in order to raise or lower the measured pressure so that it falls within its operating bounds. This response can influence other temperature or pressure controllers to change system temperatures or flow rates or directly manipulate valves, pumps, and other equipment to affect the measured pressures. Pressure protection for vessels that operate at elevated pressures must be evaluated to determine whether passive pressure protective devices are sufficient or active pressure control systems are needed.

Depending on process specifics, other controllers such as liquid level and compositional may also be needed. The need for such controllers will be evaluated during the plant design and development process.

Safety Systems

The CTF hydrogen test facility will include both manually operated safety equipment and automatic safety systems, as appropriate for the specific hazards that may be encountered in testing the different hydrogen production processes. The individual hydrogen plant designs will provide some inherent safety protection by virtue of their physical structure and operating control systems, but additional safety systems will be required to protect personnel and equipment in the unlikely event of control system failures, fluid leaks, fires, or similar problems. Depending on the degree of protection desired, automatic safety systems can be tied in with the plant control systems so that the plant's temperature, flow, and pressure controllers can automatically place the plant in a safer condition in the event of a safety problem. Before startup and periodically during regular operation, regular safety audits and safety inspections will be performed to ensure that all safety equipment and systems are in place and operational.

Other safety features to be provided in support of the hydrogen production test program should include fire extinguishers, safety showers, eye wash stations, and other safety equipment to protect personnel working in the vicinity of the hazardous chemicals used in the SI and SE processes. Fire alarm pull boxes will be placed along worker access routes as needed to allow quick notification of fire and safety personnel. The facility will be adequately lighted and well marked with safety signs. Walkways and access areas will be demarcated by pathways. Catwalks and hazardous areas must be marked accordingly. Catch basins will likely be required for the SI and SE processes to ensure capture and containment of the hazardous chemicals in the event of leaks or ruptures in the systems during operation. Earth berms and/or blast walls may be incorporated into the site plan to protect against potential detonation of stored or accumulated hydrogen and oxygen product gases. However, except for limited product gas storage requirements—the need for hydrogen to be injected into the feed stream to the electrolysis stack during startup of the HTE process—it is assumed that most of the hydrogen and oxygen generated during experiments will be flared or released to the environment as the gases are produced.

Feedstock Requirements

The primary feedstock required for all three hydrogen production processes is the deionized and demineralized water that feeds the hydrogen production processes. Adequate water feedstock must be provided to ensure long-term hydrogen production (up to 2,000 hours operation at a time). Since the SI hydrogen production process represents the upper limit of water feedstock requirements, the requirements for this process.

As previously indicated, the SI processes will use approximately 50 MW(t) of available NGNP power to produce about 12 kg/min of hydrogen. The required feed water to produce this amount of hydrogen is approximately 108 kg/min. The required capacity should be increased by at least 30% to allow for leakage and reserve capacity and to provide a total capacity of 140 kg/min of deionized/demineralized water supply for the SI hydrogen production process. Since the modular design of the HTE process will allow testing at a lower power (5 MWe), the approximate hydrogen production rate for the HTE process will be about 2.7 kg/min. This will require about 24.2 kg/min of water as feedstock, and, with 30% contingency, the required capacity of the water feedstock delivery system is approximately 31.5 kg/min. Since these processes also produce oxygen as a product gas, the resulting oxygen flow rate is approximately 96 kg/min for the SI process and approximately 21.5 kg/min for the HTE process. These flow conditions for the two processes are summarized in Table 3.

De-aerated, deionized, and demineralized feed water must be provided on a continuous basis prior to injection into the hydrogen production processes. The water conditioning and purification system will therefore require equipment that can operate in the range of flows summarized in the Table 3.

Table 3. Flow conditions for HTE processes.

	Nominal Water Feed Rate (kg/min)	**Water Feed Rate with 30% Contingency (kg/min)**	**H_2 Production Rate (kg/min)**	**O_2 Production Rate (kg/min)**
SI Process	108	140	12	96
HTE Process	24.2	31.5	2.7	21.5

Process Chemicals

The chemicals required for the SI process include sulfuric acid (H_2SO_4) and HI. Because these chemicals are recycled, the quantity required should be sufficient to initially fill the system and provide about 30% contingency to allow recharging of the system and account for small leakages and other losses. CTF will need to provide storage for these chemicals. The exact storage requirement will have to be defined by the hydrogen system developer based on the required volume of the individual system.

Product Storage

Hydrogen and oxygen product gases may need to be stored for various reasons. Since the SI process provides the upper bounds of product storage requirements, a total storage capacity of 51,840 kg will be needed to provide for 3 days of hydrogen storage at a production flow rate of 12 kg/min. The required 3-day storage capacity for oxygen at 96 kg/min is 414,720 kg. Any remaining product gases will be vented or flared to the atmosphere. It is assumed that high-pressure (approximately 6,000 psig) storage tanks will be provided for 3 days of storage. For some of the HTE process designs, a noncondensable sweep gas may be used to remove the oxygen from the anode side of the electrolyzer stack. In these cases, the oxygen and sweep gas mixture will simply be vented to the atmosphere with no storage requirement.

Contamination and Corrosion Control

A vanadium-based catalyst usually catalyzes the decomposition of H_2SO_4 into SO_2, H_2O, and O_2 in the SI process. The catalyst, by virtue of its chemical composition and surface microstructure, lowers the activation energy of the conversion reaction between SO_3 and SO_2, thereby increasing the reaction rate. Over time, the catalyst surface can become clogged with reaction byproducts or the catalyst itself may undergo some chemical degradation, becoming less effective. Once the catalyst becomes degraded, it will have to be regenerated or replaced. The CTF facility must therefore provide support equipment to facilitate catalyst regeneration and/or catalyst replacement in the H_2SO_4 decomposition reactor.

The SI process also uses I_2 and HI, which are highly corrosive to structural materials at the temperatures of these processes. Even with corrosion-resistant materials, it is likely that some components will degrade over time due to corrosion. In the liquid process streams, it is likely that corrosion products will become dissolved or entrained. With no material outlet for these particles, due to the cyclical nature of these processes, it is possible for the concentration of corrosion particles to build up during operation. The CTF must therefore have the capability to occasionally purge these corrosive products through purge valves, recycle lines, filters, ion-exchange columns, absorbers, etc.

6. FACILITY DESCRIPTION

6.1 Civil

The siting study for the CTF facility used two approaches to evaluate potential siting areas. The first approach identified and ranked potential siting areas within the INL boundary as candidate locations for the CTF. The second approach evaluated the pros and cons of locating the facility outside the INL boundary. Both a primary and alternate siting area are identified for the INL location and the viability of using a location outside the INL Site boundary was studied. A decision must now be made as to whether the CTF will be located near Idaho Falls or within the INL Site boundary. This study assumes the CTF will be located inside the INL Site boundary because that scenario received the highest ranking during the siting study. The projected INL Site location is the CFA as discussed below.

6.1.1 Site Location

The new CTF will be located at CFA per the recommendations of the siting study (INL/EXT-08-14052, "Site Selection Study for the NGNP Component Test Facility"). The proposed location within CFA is an undeveloped area on the southernmost end, which accesses Highways 22 and 26, railways, Fire Department services, and medical services. Existing utilities such as sanitary sewer, potable water, and firewater are accessible at the site and could possibly be used for the facility. The site is relatively flat and does not contain any rock outcroppings. Rock depth is across the site is unknown, but rock probes drilled for a sewer lagoon located to the northeast of the site indicated that rock was between 4 and 8 ft deep.

6.1.2 Site Development

The 60-acre location is presently unimproved so all site improvements would be considered new work. Approximately 4 ft of engineered fill will be required to allow for adequate cover and bury depth for underground utilities. Foundations will be placed directly on rock.

A subsurface survey of the site will be conducted during conceptual design. The site will be stripped of existing vegetation, and then filled and graded for the new buildings, roads, and parking.

Grading and Drainage

It is estimated that areas to be occupied by the buildings and balance-of-plant areas will be raised approximately 2-ft in relationship to the surrounding ground elevations to provide drainage away from doors, roads, and sidewalks. The floor elevation of the facilities will be raised above the maximum elevation of the design basis flood level. Grade changes at the main entrance will be kept to a minimum to accommodate handicapped personnel and vehicle accessibility. During, construction, storm-water runoff will be managed and directed accordingly. Long-term site surface drainage will be diverted to a storm-water lagoon. Impervious surface areas and parking areas will be minimized (Leadership in Energy and Environmental Design [LEED] Points). Vehicular driveways and parking areas will be sloped to drain curbs, gutters, and storm drainage features.

Roads, Railway, and Access

Oregon Street, Lansing Avenue, and Kearney Avenue will be extended to the facility for vehicle access. A new 52 stall parking area will be constructed in front of the facility. Paved access areas, roadways, and laydown areas will be constructed around the facility and throughout the balance-of-plant area. Roadways will be designed to accommodate HS-20 wheel loading. The laydown areas and balance of plant areas will be finished with gravel. Adjacent areas not paved but disturbed during construction will be reseeded with grasses or lawn as appropriate.

A spur approximately 2500-ft in length from the existing north-south railway will be run to the facility for delivery of consumables and equipment.

Reinforced concrete sidewalks, door stoops, and approaches will be provided to facilitate personnel and vehicle access to the facility. Provisions for safe entry to the administrative areas by handicapped personnel will be provided.

A 6-ft chain link fence will enclose the CTF site.

6.1.3 Meteorological Conditions

Temperatures

Average monthly temperatures range from 15.8°F (-9.0°C) in January to 68.2°F (20.1°C) in July. Recorded extremes at CFA are from -47°F (-44°C) to 101°F (38°C). Average monthly relative humidity ranges from 15% in August to 89% in October and December.

Wind

Atmospheric stability at INL is based on time of day, time of year, and cloud cover. Annual hourly average wind speeds, measured at heights of 20 and 250-ft (6 and 76 m), are 7.5 and 12.6 mph (3.4 and 5.67 m/s), respectively. The greatest hourly average wind speeds measured were 51 and 67 mph (23 and 30 m/s). Peak gusts have been measured at 78 and 87 mph (35 and 39 m/s). Only three tornadoes have been recorded at INL, none of which resulted in any damage.

Precipitation

Annual precipitation received at INL averages 9.07 in. (23 cm) and has ranged from 4.5 to 14.4 in. (11.4 to 36.6 cm). Maximum observed 24-hour amounts are less than 2.0 in. (5.1 cm), and the maximum 1-hour amount is 1.19 in. (3.0 cm). Maximum precipitation is usually received in May and June with the minimum occurring in July. Snowfall generally occurs between November and April, totaling an annual average of 26.0 in. (66.0 cm). The range of annual snowfall totals is 11.3 to 40.9 in. (28.7 to 103.9 cm). The maximum 24-hour amount is 8.6 in. (21.8 cm).

6.2 Structural

6.2.1 General

The main CTF facility (see Figure 14) will consist of steel columns and girders supported by reinforced, cast-in-place concrete piers and 12-ft × 6-ft × 28-in. spread footings on the main High-Bay columns. The ground floor will be reinforced, slab-on-grade, approximately 12-inches thick to accommodate heavy traffic and material handling loads. The wall construction will generally be light gage steel. Some walls will be reinforced concrete supported by reinforced concrete wall footings, as required for deflagration safety. The High-Bay area will contain multiple overhead top-rolling bridge cranes that clear spans of either 100 or 120 ft. Two tiers or levels are planned for the overhead cranes to offer maximum flexibility to the spaces below. The variety of cranes provided will include a 200-ton crane on the top rail and 25, 50, and 85-ton cranes on the bottom rail for each span of the High-Bay. The facility is to be designed such that the structural system can accommodate up to a total crane capacity of 500 tons.

The roof structure of the facility will be constructed of steel deck supported by open-web joists.

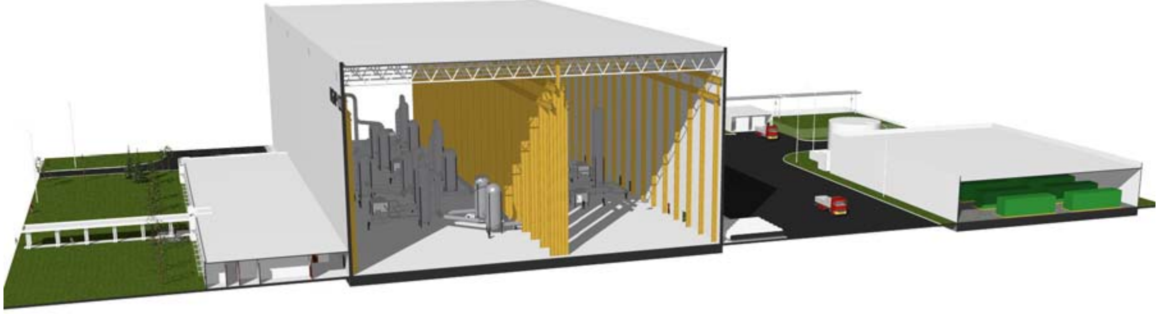


Figure 14. Cutaway view of proposed CTF.

6.3 Architectural

6.3.1 CTF

The test loop configurations are arranged in what is described on the drawings as the Component Test Facility (CTF) High-Bay. The High-Bay encloses a space that is approximately 400 × 220 × 96-ft high at the top of the parapet and is served by multiple overhead top rolling coped bridge cranes that clear spans of 100 and 120 ft. The footprint size of the High-Bay was determined by the space needed to enclose the test loops configured in this package plus 30% for future growth and an interior material receiving and loop modification/lay-down area. The CTF height was determined by the clearance required for the tallest test vessels modeled in this package and the space to configure the overhead bridge cranes, roof framing, and roof drainage to interior drains.

A variety of crane sizes will be provided over the High-Bay. A 200-ton bridge crane will be provided on the crane rail beam with another 50-ton bridge crane for each span of the High-Bay. The crane rail beam will be configured into the building in a stepped column configuration. The High-Bay facility is to be designed such that both spans will initially support a 200-ton crane and a 50-ton crane and will have the capacity to handle an additional 200-ton crane, should the program dictate. The total initial crane design capacity of the High-Bay will be 500 tons. The design intent would allow the additional 200-ton crane without any structural modifications to the CTF.

Manifold utilities will be provided along the longitudinal walls at various heights and coordinated with mezzanines and service connection locations. Numerous mezzanines, catwalks, ladders/cages, platforms, etc., are anticipated in this space, but are not shown for clarity at this stage of design. Stairway access and egress is provided at each corner of the High-Bay.

A bottom rolling, multitrack, multisyllabic retractable wall will allow the receiving end of the High-Bay to be opened to the exterior mock-up/staging pad. This feature combined with the mock-up/staging pad will allow configuration of larger assemblies prior to transport by rail into the High-Bay under the overhead cranes. This same area is also supported by a new rail spur from the existing CFA rail road service.

The administrative office area (76 × 360 × 15 ft) is located adjacent to the High-Bay to maximize support functions and is separated by common wall. The common wall between the CTF High-Bay and the administrative office area will serve as a fire resistant wall and also designed to resist missiles generated by the potential explosive release of high temperature and pressure fluids from the test loops in the High-Bay to the occupied administration areas beyond. Total square footage for the administrative area is approximately 37,400 ft^2. The total enclosed area for the CTF is approximately 404,150 ft^2, which excludes the square footage of other support buildings throughout the campus in the enclosed fenced area. Table 4 below summarizes the space allocation requirements for the administrative and High-Bay areas.

Table 4. Space allocation for administrative and High-Bay areas.

Space	Square Footage (ft^2)
Conference room for 40 people	750
Small conference room for 10 to 15 people	400
2 Large training classrooms for 15 to 20 students and instructor	775 each
2 Small training classrooms for 10 students and instructor	375 each
4 Offices for instructors	135
4 Manager offices	1,000
Staff offices 130 ft^2 each (19)	2,470
Central control room	500
I&C development lab	1,000
I&C component storage	250
Central I&C network room	120
Loop I&C network rooms (3)	360
Loop control rooms (5)	600
Lobby, reception, restrooms, showers, lockers, lunch area, janitor	4,250
Video conference room	300
Laboratories with service corridor (6)	2,000
Sample storage	200
Maintenance repair room	120
General storage rooms	TBD
Uninterruptible power supply (UPS) room	200
Electrical room	300
Generator room	225
Central computer room	500
Communications/dial room	1,500
Network closets (3)	130 each
Telecommunications room	200
Shipping and receiving loading dock	800
Machine shop/stock room/office	1,000
Compressed gas storage room	100
Loop mockup and assembly area (exterior pad)	58,000
High-bay for test loops with multiple bridge cranes	134,000
Large 480 V electrical rooms (2)	2,500
High voltage switchgear room	1,200
UPS room	600
UPS battery room	1,200

The CTF will be enclosed with a prefinished insulated panel system over steel and/or concrete structure in certain areas as dictated by design. Due to the height of the High-Bay and the extreme loads carried by the overhead cranes, there will be a super steel structure to support the loads and to meet seismic design.

The roof will have an interior drain system into a storm water pond which will be designed to receive drainage from all impervious surfaces and recycled where possible (LEED Points). The interior roof drainage design at this extreme height will avoid run-off at the eaves and its related hazards at this height. The roof will be thermally insulated R-38 min. and be Sarnafil single-ply reflective roofing system (LEED Points).

The testing loop configurations are arranged in the High-Bay area.

The interior walls of the High-Bay will be exposed structure and painted white for light reflectance (LEED Points). The interior walls of the Administrative Area will be painted drywall with few exceptions. The high traffic areas (hallways/labs, etc.) will be vinyl and areas requiring more durability (Machine Shop, Stock Room, Generator Room, etc.) will be painted concrete masonry unit.

The glazing will be insulated "low E" reflective and/or tinted glass (LEED Points). The glazing and any skylights will be configured to minimize ultra violet (UV) gain, conserve energy, and offer security protection to the occupants.

Green and/or sustainable design principles have been introduced into the administration structure by the use of light shelves to regulate and enhance light at the perimeter for the offices, classrooms, and most populated areas suited for day-lighting. Most of the offices, classrooms, and conference rooms have been arranged at the perimeter for this reason (LEED Points).

The various architectural building designs for the new CTF facility are based on the technical and functional requirements, the individual lab space allocations, circulation, lab and support interrelationships, structural shape, site, orientation, and other design requirements. Each building has taken into account the anticipated function of the activities that are to take place within and the relationship of the various buildings to each other in support of the overall testing activities.

The CTF facility design configuration groups and separates different types of activities and buildings from one another to enhance functions, safety, and operations. These separations result in three primarily different activities being accounted for: the high temperature and pressure test facility, the hydrogen production test facility, and the assorted support buildings and utilities.

6.3.2 Hydrogen Process Building

The building to house the HTF processes is based on the high-temperature electrolysis (HTE) process and is 20,000 sf in size (see section 5.4.2). The building is a metal building approximately 115 × 174 × 50-ft with a 50-ton overhead crane. Floors will be 8-inch thick, reinforced, slab-on-grade concrete. Spread footings bearing directly on rock, with reinforced concrete piers will provide a foundation for the building. The building will contain a small administrative area (1,725 ft^2) containing a restroom, telecommunications room, control room, two offices, and electrical rooms.

6.3.3 Balance of Plant Buildings

The balance of plant buildings are summarized in Table 5. The balance of plant buildings will be metal building systems with metal siding and metal roofs. Floors will be 6-inch reinforced concrete slab-on-grade with a reinforced concrete pier and spread footing foundation system. The generator building generators will be mounted on isolation footings approximately 2-ft thick minimum.

Table 5. Space allocation for Balance of Plant buildings.

Space	Square Footage (ft^2)	Building Height (ft)
Warehouse	51,970	24
Grounds & Maintenance Building	2,400	20
Water Process Building	7,297	16
Generator Building	30,090	20
Potable Water Well Building	1,600	12
Deep Well Pump Houses	1,600 each	12
Fire Water Pump Houses	600 each	12
Industrial Waste Pump Building	7,297	12
Industrial Waste Treatment	900	20

6.4 Utilities

6.4.1 Fire Water

Water supplies for fire protection will be separate from other plant water uses, including potable water, and be arranged to provide 100% redundant water storage and pumping capabilities. Distribution storage of firewater will be arranged such that it is regularly turned over by designing the firewater tanks to allow them, via a cascading system, to fill the plant process water storage tank(s). This will keep fresh water in the tanks and allow the water passing through the firewater tanks from the deep well to effectively prevent the firewater tanks from freezing.

The firewater distribution system will be arranged so that all exterior portions of a building are accessible within 250 ft of hose lay from a fire hydrant and each building will have coverage from a minimum of two hydrants. The underground distribution system will be designed to ensure that no more than five devices such as sprinkler systems or hydrants will be impaired at any time due to a single break in the system.

Underground firewater piping will be arranged to resist damage during a design bases earthquake by using cement-lined ductile iron pipe connected together using joint restraint methods that do not rely solely on thrust blocks.

Large facilities containing multiple sprinkler systems will be arrange in a manner that no more then one system will be out of service at any one time due to a single impairment of the underground fire water distribution system.

6.4.2 Potable Water

CFA contains one 150 hp and one 125 hp deep well for a total flow of 1,200 gpm. Two additional deep wells with pumps will be constructed to provide raw water for the cooling towers and HTE system. Two 1.5 million gallon tanks will be provided for raw water supply. Existing groundwater is located at a depth of approximately 600 ft.

6.4.3 Sanitary Sewer

A new CFA sanitary sewer system including a lift station, force main, treatment lagoons, and a pivot irrigation land application system was constructed in 1994. The flow capacity is 250,000 gpd, the pumping capacity at the lift station is 350 gpm at 70 TDH (total dynamic head), and the pumping capacity to the pivot is 400 pgm at 115 TDH. Provisions in the estimate and drawings have been made for a new sanitary sewer system, but it is likely that the existing sewer system could be used for the CTF. The new system will consist of a 2000-gallon septic tank with a drain field. See appendix A for the sewer piping layout drawing.

6.4.4 Industrial Waste Water

Process waste water from the purified water treatment process (and other processes, if required) will be routed to an industrial waste treatment building and eventually discharged into an industrial waste water evaporation pond.

6.5 Balance of Plant

6.5.1 Compressed Air System

Compressed air of instrument air quality will be provided. Higher quality and filtered air can be provided at the source as needed.

6.5.2 Breathing Air System

It is assumed that normal operations will not require breathing air (Grade D) for personal protective equipment. The building ventilation rates and oxygen monitors will suffice for normal operations.

6.5.3 Purified Water System

The purified water technology (reverse osmosis, distillation, deionization, and demineralization) will consider the well supply water and the contaminate levels that can be tolerated by the CTF. Contaminants, typically include particulates, inorganics, organics, and microorganisms. Highly purified water for specific test can be provided at the source as needed.

6.5.4 Auxiliary Cooling System

Cooling Tower

It is suggested that a closed-circuit cooling tower be used in the auxiliary cooling system to cool the fluid. The cooling fluid's temperature before it enters the cooling tower circuit reaches a maximum temperature of approximately 50°C. The cooling tower cools the cooling fluid down to approximately 25°C. The maximum water temperature at the inlet to the heat exchanger is approximately 30°C.

Cooling Pumps

The cooling pumps required in the auxiliary cooling system should supply the coolers with water at approximately 20 kg/s. A single stage centrifugal pump is suggested with a 600 kPa pressure rise at the supplied flow rate. An additional pump is suggested for redundancy.

Cooling System Piping

The cooling system piping comprises the piping between the cooling tower and helium coolers. The minimum required pipe size is a 100 mm Nominal Bore.

Water Treatment System

The cooling water systems require proper chemical treatment to prevent problems associated with component corrosion, scale, fouling, and microbiological contamination, which can lead to secondary problems such as poor heat transfer and, ultimately, component degradation.

Air-Cooled Condenser

The air-cooled condenser is used in steam generator tests. The details for this condenser will only be determined once details of the steam generator tests have been defined. The condenser will typically have a capacity of 15 MW at 5 kg/s.

6.5.5 Helium Inventory and Control System

The main function of the helium inventory and control system (HICS) is to supply, extract, and maintain helium inventory within the process loops. It should have the ability to either fill the system from bulk helium containers or from the storage vessels located onsite. The HICS should be able to pump helium from the containers or vessels at a pressure that is lower than the process pressure.

HICS Components

Helium Storage Vessels. The helium storage vessels are used to store the process inventory during maintenance or repair periods when the complete inventory is not to be wasted. It is suggested that the storage vessels have the capacity to store the entire inventory of the process— primary and secondary loop. The entire inventory will be stored at an estimated pressure of 14,000 kPa to reduce the require storage volume. The volume of the primary side and secondary side of the loop is about 200 to 300 m^3. The total calculated volume of the storage tanks are 130 to 190 m^3 at 14,000 kPa. The storage vessels' volume is currently limited to approximately 16 m^3. Ten to 12 of these vessels are required to store the entire inventory. These vessels will be about 1.5 m in diameter and 10 m long. Tradeoff studies need to be performed during the preliminary design to determine the cost implication of investing in hardware such as the helium storage vessels and the cost of loss-of-inventory.

Inventory Transfer System. The inventory transfer system is used to transfer helium from the bulk helium containers and the storage tanks to the primary and secondary process loops and back. The system consists of isolation and control valves as well as a positive displacement compressor unit. The compressor unit is used to transfer the fluid when the pressure of the volume to which the fluid is transferred is higher than the system from which it is pumped. The maximum pressure of the storage vessels determines the size of the compressor and the time required to fully transport the inventory of the process.

The different modes of the inventory transfer system are illustrated in Figures 15 through 19. Figure 15 shows the process flow diagram when the loop is supplied with helium when the pressure in the loop is higher than the pressure in the storage tanks. Figure 16 shows the process flow diagram when the loop is supplied with helium when the pressure in the loop is lower than the pressure in the storage tanks and the compressor is not needed. Figures 17 and 18 show the process flow diagram when the helium is extracted from the loop when the pressure in the loop is (1) higher than the pressure in the storage tanks and the compressor is not needed, and (2) lower than the pressure in the storage tanks and the compressor is needed to increase the pressure in the storage tanks. Figure 19 shows the process flow diagram for the conditioning of the low pressure vent tank, which can be used when a pipe break is simulated to suddenly extract the inventory. The pressure in the low pressure vent tank is reduced significantly to simulate a postulated pipe break scenario. However, the tank should be located close to the loop where the pipe break scenario is simulated to reduce the inertia effects of the gas.

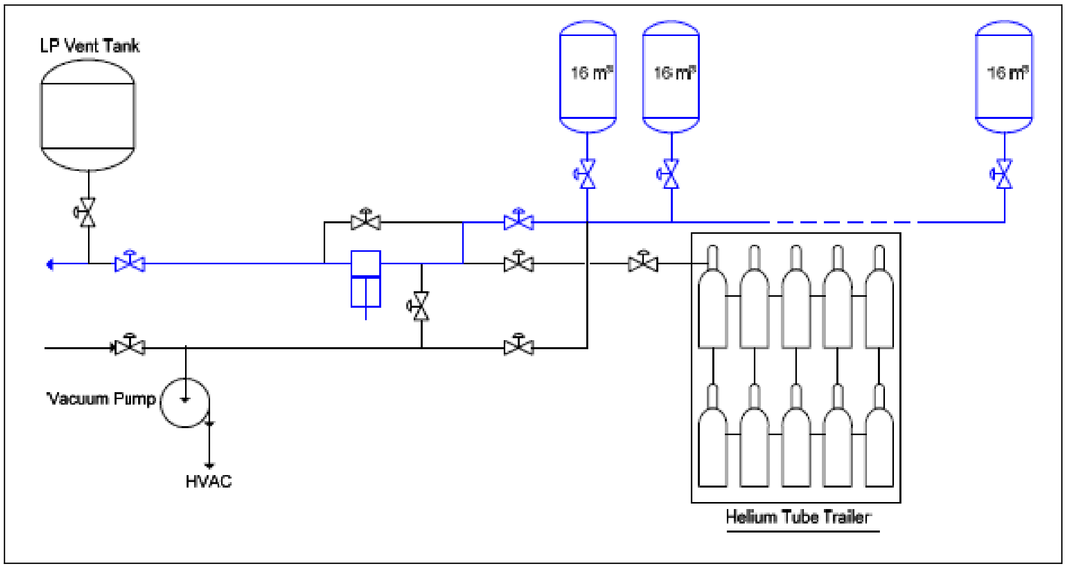


Figure 15. Helium injection into system when the process pressure is higher than the storage tank pressure.

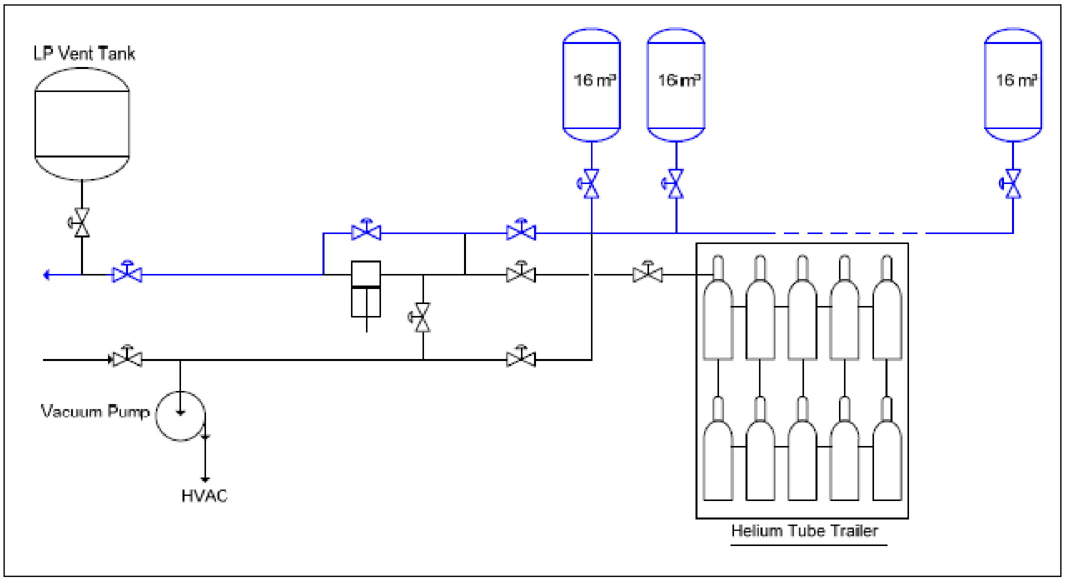


Figure 16. Helium injection into system when the process pressure is lower than the storage tank pressure.

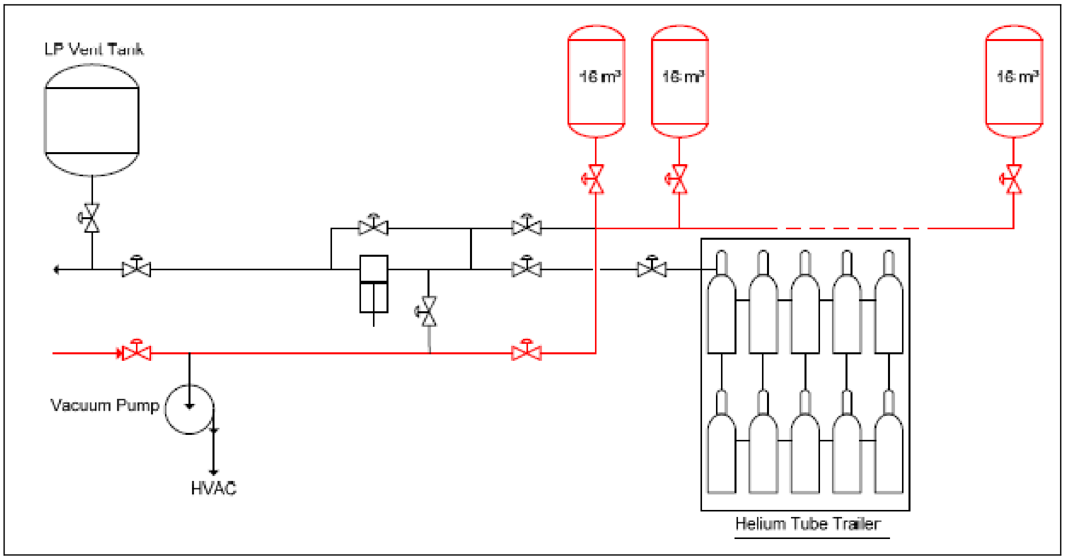


Figure 17. Helium extraction from the system when the process pressure is higher than the storage tank pressure.

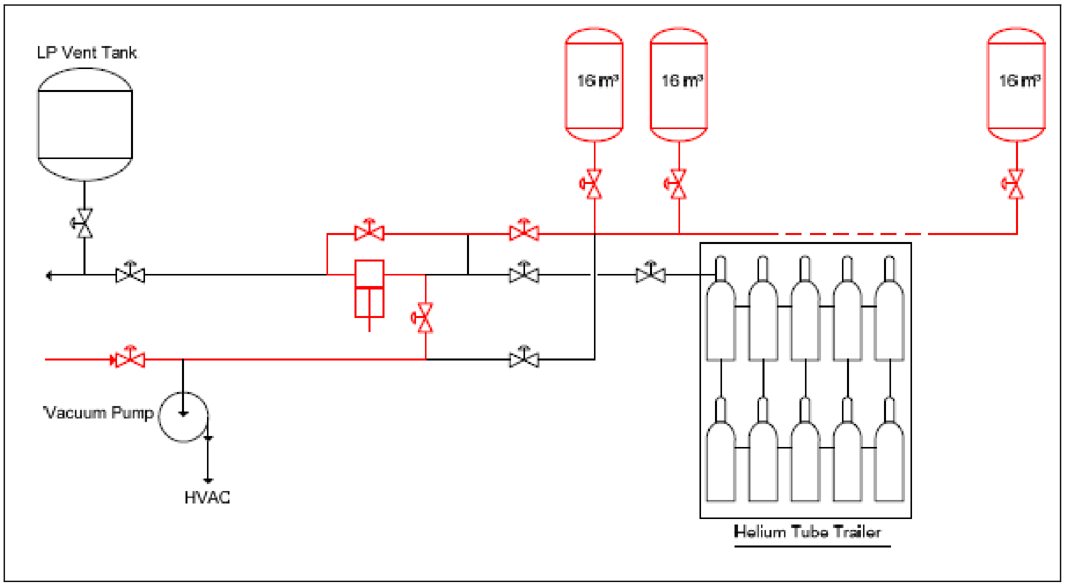


Figure 18. Helium extraction from the system when the process pressure is lower than the storage tank pressure.

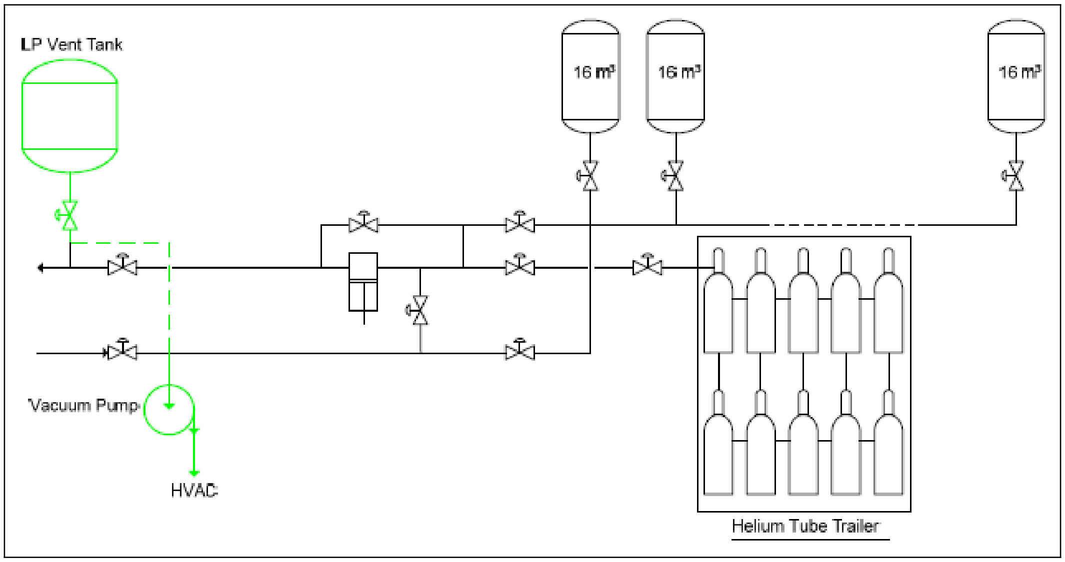


Figure 19. Conditioning of the low-pressure vent tank.

6.5.6 Helium Purification System

Purification Requirements

It is envisaged that the general purification requirements for the CTF would be to remove H_2 and CO from each of the primary and secondary loops to restrict the deposition of carbon on metallic surfaces, particularly ferritic steels, at high temperatures (~500°C). The moisture content in the primary loop in particular, must be removed as it will react with the dust from the dust generators to form H_2 and CO_2. Residual oxygen from air after purging will also react with the dust from the dust generators to form CO and CO_2.

Water and carbon dioxide will be removed and kept under allowable limits (to be specified). It is expected that a large amount of impurities would be present after initial evacuation. It is further suggested that the dust from the dust filters be heated and purged separately to reduce the amount of moisture and oxygen present before operation.

Process Description

Pressure swing adsorption is used to remove impurities from the helium stream. A molecular sieve membrane or packed bed is used at high pressures and low temperatures to adsorb H_2O and CO_2. The packed bed or membrane becomes saturated after time and needs to be regenerated. The regeneration process consists of blowing pure helium at elevated temperatures and low pressures in the reverse direction of the main process, whereby the impurities are removed from the molecular sieve. Since there will be no radioactive isotopes such as 14 or 3, the regeneration gas can simply be blown to the off-gas. The H_2 and CO must, however, first be converted for the adsorption process in the molecular sieve.

HPS Components

Dust Filters. Since there will be dust generators, a filter or cyclone will be required to remove dust that enters the HPS. This will be necessary to ensure that the packed beds that remove impurities from the gas stream function as desired. Because of the potentially large amounts of dust generated, it is suggested that the gross amount be filtered with a cyclone or prefilter followed by fine dust filters. The prefilter will enhance the efficiency and operable life of the fine dust filters.

Copper Oxide Catalytic Convertor. The copper oxide catalytic converter oxidizes H_2 and CO so that it can be adsorbed in the molecular sieve. The CuO beds require a temperature of approximately 210°C with an oxygen supply to regenerate the bed after a period of oxidizing the CO and H_2.

Coolers. After the H_2 has been oxidized to H_2O in the CuO beds, it is recuperated and cooled using the feed from the loop and cooled further using a chilled water heat exchanger. This will ensure that most of the water is condensed and serve as a cooling medium for the gas stream for the adsorption of the impurities in the molecular sieve.

Water Coalescer. A water coalescer is installed after the coolers to remove the water from the gas stream. This is necessary because water ingress in the molecular sieve will greatly reduce the adsorption capacity.

Molecular Sieve. The molecular sieve will remove the remaining H_2O and CO_2 from the helium stream. Two, type 13X molecular sieves with an effective pore size of 1 nm are suggested in parallel. While one is used to adsorb the impurities, the other is regenerated. The molecular sieve sizing will depend on the amount of impurities remaining in the system after evacuation and purging.

Circulators. If the HPS is to be used to remove impurities before operation, a circulator will be required in parallel with a valve to recalculate the helium. During normal operation, a control valve will be used to control the amount of flow through the HPS due to the differential pressure.

6.6 Fire Protection

Automatic fire sprinkler protection will be provided throughout all facilities installed as part of the CTF. This fire protection will follow all applicable National Fire Protection Association (NFPA) codes and standards, International Building Code (IBC) counsel such as the IBC and International Fire Code, and DOE requirements. Additional requirements may be obtained from other sources such as Factory Mutual Global, which is based on specific hazards encountered during design.

In addition to automatic sprinkler systems, structural protection will be provided by a combination of water spray and high-density fire proofing in areas where jet type fires are anticipated from the pressurized hydrogen system. Water mist will be evaluated for use in turbine and generator enclosures. Firewalls, designed to also resist missiles generated by the explosive release of high temperature and pressure fluids will be provided to separate support areas, (offices, conference rooms, data centers, cafeterias, etc.), not directly involved in any test activities. Deluge fire suppression will be provided in all combustible cooling towers.

Space separation will be provided between the hydrogen production and storage facilities, and between all major electrical transmission lines and substations, and other major facilities.

Water supplies for fire protection will be provided from two redundant firewater storage tanks, each having the capacity to hold two hours worth of water with the fire pump running at 150%, which gives an anticipated working volume of 450,000 gallons per tank. The tanks will be welded steel suction tanks, arranged such that an impairment of one tank or a catastrophic release of water from one tank will not impair the other tank.

Two fire pumps, one associated with each tank, will be provided to supply the firewater distribution system with firewater. Each fire pump will be driven by a diesel engine and capable of meeting 100% of the firewater system demands.

The firewater pumps will be sized based upon the maximum anticipated firewater demand being within 10% of the fire pumps rated flow. The fire pump discharge pressure will be capable of meeting all anticipated fire system demand pressures without installing a separate booster pump at any building. The fire pumps are currently anticipated to require a rating of 2,500 gpm at 125 psi to meet the cooling tower and structural steel protection demands.

Specialized fire detection systems will be provided throughout the hydrogen production and storage areas. Hydrogen leak detection will be provided in a manner that is capable of detecting a small leak. Use of area leak detection at the ceiling is not considered capable of meeting this requirement in a large area or high airflow area.

The fire alarm system for the CTF will use the latest Underwriter's Laboratory (UL) Edition 9 equipment and be capable of providing digital voice and mass notification throughout the CTF area. The fire alarm control panels will be networked together via fiber optics and capable of providing remote start commands to the firewater pumps. The fire alarm fiber-optic network will be routed to the INL fire dispatch center at CFA.

6.7 Electrical

6.7.1 Electrical General

An estimate of the peak electrical power demand for the CTF complex is dependent on the NGNP component test schedules and will be further developed during preconceptual design where draft component technology development road maps and associated component test plans will be prepared. In the absence of these test plans, assumptions were made and this study was prepared based on operating a number of test loops simultaneously.

The estimate shows that the electrical demand for the CTF and hydrogen processes cover a range from 8 to 60 MWe, depending on which test loops and processes are operating. An addition capacity of 30% for the CTF and 10% for the hydrogen (sodium-iodine), was added for a maximum demand of up to 96 MW. These loads envelope the expected demand of the complex. This power will be distributed to the buildings of the CTF complex from a new substation sized for a pair of 50 MVA three-level cooling power transformers (four total) in a double ended substation configuration for a 100, 133, and 166 MVA capacity.

The large building load centers are the CTF, hydrogen process building, and water process building. The typical methods of power distribution from the substation to the various buildings are assumed to be overhead cable bus or utility tunnels. It does not appear to be practical at this time to run the power in duct banks. The spreadsheets for the power estimate are attached in Appendix B. The utility feed and CTF substation are discussed in Subsection 6.7.2 and the building electrical systems are discussed in Section 6.7.3. The schedule for the electrical power needs of the CTF complex is presented in Figure 20.

An electrical estimate and allowance was made for standby generator power needed to safely shutdown the test loops. It was assumed that safe shutdown involved operating the process circulators and cooling system to remove heat from the process to some acceptable level. The same set of operating equipment and future capacity as the general electrical estimate were used for the standby power estimate. The estimate showed that the required standby power was 16.6 MW with 4.3 MW future capacity for a total of 20.9 MW. With an estimated run time of 2 days, a two times safety factor, a fuel consumption rate of 0.0607 gal/kW/hr, and using No. 2 diesel, the total fuel supply would need to be approximately 125,000 gallons (excluding the needs for diesel fire pumps). The standby power system (SPS) are discussed in Subsection 6.7.4.The size of uninterruptible power supply (UPS) needed to safely shutdown the test loops was estimated. It was assumed that safe shutdown will involve operating the process circulators active magnetic bearings (AMB) and the controlling I&C systems to remove heat from the process to some acceptable level. The same set of operating equipment and future capacity was used for the UPS estimate, which showed that the UPS power required was 2.0 MW with 0.6 MW future capacity for a total of 2.6 MW.

The following assumptions were made in preparing this report:

- The electrical loads in the CTF complex can be supplied by 13,800 V, 4,160 V, 480 V three phase power or 120/208Y low-voltage power. Large loads, roughly defined as greater than 10 MW, will be fed by the 13,800 V systems; medium sized loads, roughly defined as 2 MW to 10 MW, will be fed by 4,160 V systems; smaller loads, individual loads smaller than 2 MW will be fed by 480 V systems; and the smallest utilization loads will be fed by 120/208Y V systems.
- The utility will be able to supply the required power within the projected schedule.
- The individual process pieces of equipment power estimates were derived from the process flow sheets and process energy balance models.
- The process support loads have been estimated from an engineering assessment of the typical efficiencies and rules-of-thumb for the process loads.

A number of ancillary systems are required for this complex in addition to the electrical power systems. These include: fire alarm, emergency mass notification (evacuation), building management systems (BMSs), facility monitoring system (FMS), video, safe shutdown system, public address (PA), grounding, lightning protection, and security.

A new underground electrical duct bank system will be required between the CTF complex buildings to support future growth in the CTF complex. For estimating purposes, this system is assumed to have four 5-in. ducts for electrical power, one 5-in. duct for SCADA, and one 5- in. duct for the spare (for a total of six 5-in. ducts. A manhole will be required just outside each major building at intervals of 300 ft. This system will start at the CTF boundary manhole and extend throughout the CTF complex.

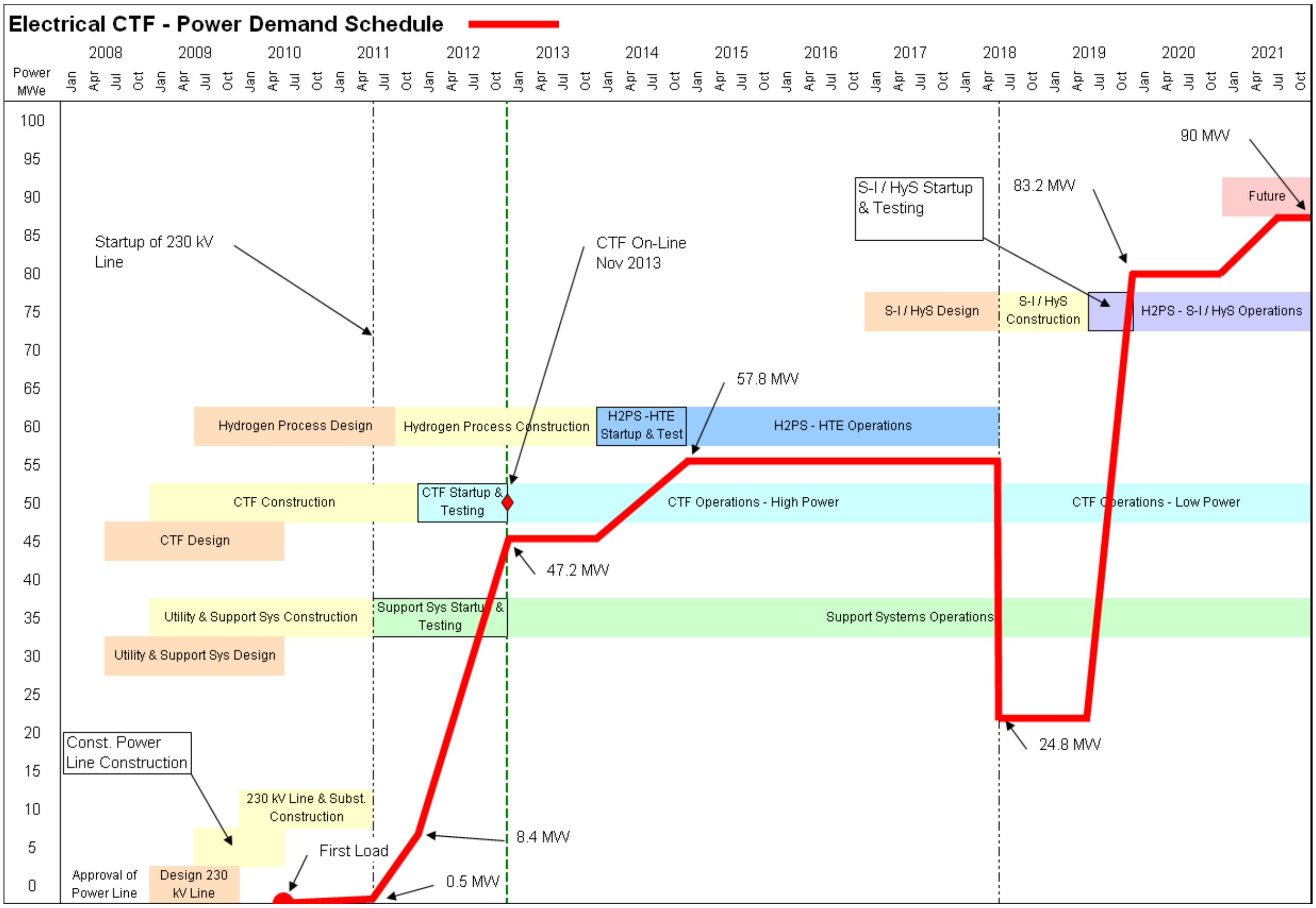


Figure 20. Power schedule.

6.7.2 Site Power Supply

Power for the site will be provided by a commercial utility at transmission voltage of 230 kV. The transmission lines will feed a new electrical substation, which will transform the voltage to 13.8 kV for facility utilization. It is assumed that the utility will have ownership and maintenance responsibility over the high-voltage portion of the substation down to the transformer secondary breakers. The transformer secondary breakers will be the metering point of billing where the site facility will take over ownership and responsibility of the power system. Because interruption of power to the facilities will result in undesired costs and delays the utility will provide a service with a System Average Interruption Frequency Index of less than 0.002. The substation will be designed with two transformers per bus so that loss of a transformer due to failure or maintenance will not result in a facility power outage.

The substation will contain four 50 MVA transformers with a no-load tap changer on the primary and a load tap changer on the secondary in a dual ended bus configuration. These transformers will require the ability to operate in parallel and the ability to operate in the step-up and step-down mode. The transformer oil will be readily biodegradable and nonbioaccumulating such as Envirotemp FR3 fluid manufactured by Cooper Power. The transformers will be protected by a relaying package that will include transformer differential, overcurrent, and sudden pressure rise functions. Other equipment in the substation will include an SF6 circuit breaker, SF6 circuit switchers for transformer protection, lightning arresters, and potential and current transformers for metering and protection. The substation will be connected to a SCADA system for remote operation. The substation structures will be low profile design and the yard will be fenced.

An overhead construction power line may be needed depending on the final location of CTF site. It is assumed that the line would be run from the existing CFA substation (Scoville) and would include a step-down transformer to 480V three phase power. For planning purposes it is assumed that the construction loads would be served by a 500 kVA capacity system.

6.7.3 Building Electrical

Normal power service to the CTF, hydrogen production facility, and water process building will be provided at 13.8 kV three-phase from the new substation. The 13.8 kV, 4160 V and 480 V switchgear will be a double-ended with bus tie breaker configuration to allow flexibility for outages and maintenance activities. The system will be configured to allow load testing of the diesel generators without power interruptions to the facility loads.

The 13.8 kV, 4160 kV and 480 V circuit breakers will be monitored , by a SCADA system for power quality, status of critical loads, and metering, as a minimum. The circuit breakers will also be tied into the SCADA system for load shedding purposes in the event normal power is lost. Facility loads will be classified and given a priority status for load shedding during a power outage. Based on the number of diesel generators that come on line during an outage, certain loads will remain on line based on their priority. Loads designated as “Noncritical” will be brought back on line after normal power is restored.

The 13.8 kV primary feeders from the main substation to the CTF, hydrogen generation facility, and water process facility will be routed through overhead 15 kV cable bus. Power within the facilities will be distributed through wiring inside metal conduit.

The system will perform the following:

- Provide 13.8 kV power to the CTF to operate the ITL, large component qualification circulator and supply power to 15 MVA 13.8 kV/4160 V and 13.8 kV/480 V transformers. The 4160 V supply will power TDL heaters and helium purification compressors. The 480 V supply will power building HVAC systems, 208/120 V panels (lighting, receptacles etc), and instrumentation/control systems via step-down transformers. The 480 V supply will power a UPS system, which in turn will supply the AMBs and process instrumentation.

- Provide 13.8 kV power to the Water Process Facility to supply 13.8 kV/4160 V and 13.8 kV/480 V transformers. The 4160 V will supply power to large chillers and two high capacity deep well pumps. The 480 V will supply power to various pumps, cooling tower pumps and fans, facility HVAC, 208/120 V panels (lighting, receptacles etc) and instrumentation/controls via step down transformers.
- Provide 13.8 kV power to the Hydrogen Process Facility to operate the large process heaters, large process system pump and 13.8 kV/480 V transformers. The 480 V will supply power chemical process loads, facility HVAC and 208/120 V panels (lighting, receptacles etc) and instrumentation/controls via step down transformers.
- Integrate with the diesel generator standby system to provide power to critical facility loads.
- Provide power to auxiliary facilities and systems. The system will be sized to provide a 30% spare capacity for future growth.

6.7.4 Standby Power Supply

The standby power system supports the safe shutdown of loads, including the process circulators and cooling system, during loss of site power or onsite power system failure.

The SPS will be designed, maintained, and operated in accordance with Article 701 of the NEC, NFPA 110, IEEE-336, and DOE Standard 3003. The SPS and connected loads will be inspected and tested in accordance with the latest edition of IEEE-336.

The SPS will be designed to allow maintenance and testing of the generators without loss of power to the supplied loads.

For planning purposes, it is assumed that seven 4.12 MW diesel generators operating in parallel will be needed. The generators are operating in an N+2 configuration. It is assumed that one generator will be down for maintenance at any time, leaving an N+1 arrangement. If one generator fails to start there will be five left. A priority-based load shedding scheme will be implemented to match the load to the available generator power.

The status of each generator and major circuit breaker in the SPS to the 480 V level will be monitored by the FMS to insure configuration control. Also, the SPS main feed circuit breakers will be monitored for power quality, status, and metering. Power status (quality and loss-of-power to important loads) monitoring should be included as inputs (using acceptable isolation) to the FMS.

6.7.5 UPS Power Supply

The UPS system will provide power to vital loads without interruption on loss of off-site power. Its purpose is to provide power to and protect sensitive loads, particularly computer based controllers and circulator AMB controller equipment from power interruptions. It is estimated that the UPS size will be 3 MW and will support that load during the 15 second startup time of the backup generators. UPS loads will be given priority over all other loads.

The UPS will be configured to function with the wider (60 Hẓ 10%) output frequency tolerance of the standby power system generators. UPS power status (quality and loss-of-power) monitoring will be included as a feed (using acceptable isolation) to the FMS.

The UPS system will be designed, installed, tested, maintained, and operated in accordance with Article 700.12(A) of the NEC, NFPA 111, IEEE-336, IEEE-944, NEMA PE-1, and DOE Standard 3003.

As per NFPA 111, the UPS will be classified as a Type 0, Class [tbd], Level 2, Category A system. The UPS systems will be designed to meet the requirements of IEEE-519 for harmonic distortion recommendations.

The UPS will be designed to maintain independence from the normal power system (after the overcurrent protective device feeding the UPS) and will avoid single point and common mode failures (particularly from maintenance outages, earthquakes, fires, flooding, or spraying by fire sprinklers). The UPS wiring, including the normal power feeder circuit, will occupy separate conduit from other power systems and general wiring or provide at least 1 in. physical separation when within the same enclosure, see IEEE-603, Section 5.6.

The UPS will be designed to ensure ease of maintenance and testing without unduly compromising the functionality of connected loads. The UPS will be testable without loss of power to the connected loads.

6.7.6 Grounding and Lightning Protection

Because of the large amount of power supplied to the CTF complex an extensive grounding system will be required. The CTF grounding system will limit fault voltage to earth, or ground, within predictable limits and have sufficient current-carrying capacity to prevent undue hazards to equipment or to personnel, allow detection of an unwanted connection between system conductors and ground, and provide for instigation of the circuit protection devices in a ground fault. The grounding electrode system will include building perimeter ground conductors of at least 300 kcmil stranded bare copper with sufficient ground rods, with a spacing of 40 ft and a rod at each 90° bend in the electrode conductor, to insure a ground impedance of less than 5 ohms.

Each building will have a grounding electrode ring and ground rods. All the buildings and the substation grounds will be tied together via a 300 kcmil stranded bare copper conductor embedded in every duct banks. The CTF complex ground grid will be connected to the CFA ground grid in at least two locations and to the new deep-well pump casings.

All gas and air handling equipment, filter housings, gas supply, and handling piping will be solidly grounded (Refer to NFPA 77).

The following assumptions were made in preparing this report:

- The existing grounding systems would be connected to the CTF grounding system in multiple locations
- The utility will provide a substation grounding system per IEEE-80
- All major metal structural components are grounded.

The lightning protection system will be designed to the requirements of NFPA 780. It will protect facility personnel from the effects of a near lightning strike and prevent damage to the building and critical and important systems. A separate grounding electrode system will be provided. This system will be bonded to the main building, thereby grounding electrode systems. The bond point will be able to be inspected.

6.8 Communications and Alarms

The following communications assumptions were made in preparing this report:

- The existing INL voice, security, and network systems have the capacity or can be upgraded to support the CTF complex

- The CFA duct bank system has the available space to support the telecommunication, fire alarm, and security fiber-optics cable
- The CFA main voice telecommunications system can interface with a fiber-optics link to a new remote voice switch in the CTF main telecommunications equipment room
- The security cable can share the telecommunications manhole with other low-voltage signal cabling like telephone, fiber optics, fire alarm, etc.

6.8.1 Telecommunications System

It is expected that the network and data needs of this facility will be significant. A robust infrastructure with high capacity connectivity for both internal and external systems will therefore be needed. See section 5.11 for more information. The CTF network backbone forms the core of the information technology installation infrastructure. There will be at least two backbones; a public network to interconnect office users with the INL intranet, and a private restricted local area network to interconnect control system components and building automation applications.

The CTF complex will have a number of different networks. When a network must interface with the internet, a demilitarized zone demarcation point will be established. Physical telecommunications and networks will follow the applicable Telecommunications Industry Association (TIA), Electronic Industries Alliance (EIA), and Institute of Electrical and Electronics Engineers (IEEE) standards for switched public network deployment.

One voice/data outlet will be installed per every 50 ft^2 of office space with a minimum of two outlets per office on opposite walls. One data outlet will be installed per each student location in the classroom space, a data outlet will be proved at the instructor’s lectern, and a minimum of two outlets on each wall. Each classroom will have a voice wall phone near the entry door. The conference room(s) will have two voice/data outlet at the conference table, a data outlet at any projector points, and a minimum of two voice/data outlets on each wall. Each voice/data outlet will be wired with four, eight-pair, Category 6 cables (if the current technology at the time of final design provides for a higher standard or category of cabling, that standard will be used).

The CTF complex voice system should support up to 400 user handsets and 50 special pair circuits.

Each loop or process control room will have an adjacent dedicated telecommunications closet. For planning purposes the closet is expected to house two 19 in. equipment racks and be about 80 ft^2 with an overhead cable rack system. The closet will house the control room support equipment. For estimating purposes, a dedicated high-capacity, fiber-optic cable will be provided to loop and process local data acquisition and control equipment. This fiber is assumed to be a 6-strand single-mode cable. Each telecommunications closet will also be connected to the main CTF telecommunications equipment room via a fiber optics backbone. This is assumed to be a 6-strand single-mode cable. Each loop and process control room is assumed to have 12 large monitors and two printers, all served by data outlets each with four, eight-pair, Category 6 cables back to the closet. Each control room and closet will be provided with UPS power.

The main CTF and H2PS supervisory control rooms will each have an adjacent dedicated telecommunications closet that houses the control room support equipment. For estimating purposes a dedicated, redundant, high-capacity, fiber-optics backbone cable set will be provided to the supervisory local data acquisition and control equipment. Each of these fiber-optic cables is assumed to be a 6-strand single-mode cable. Each supervisory control room is assumed to have 18 large monitors served by a data outlet with four, eight-pair, Category 6 cables back to the closet. The control rooms and closets will be provided with UPS power.

A new multiple strand, high-capacity, fiber-optic cable will be provided from the main CTF telecommunications equipment room to the main telecommunications at CFA. For estimating purposes this fiber is assumed to be a 24 strand single-mode cable and the existing underground duct bank system is available at 100 ft from the CTF complex boundary. A new 8 × 8 × 7 ft telecommunications manhole will be located at the edge of the CTF boundary. For estimating purposes it is assumed that the CFA main telecommunications point is located within 1 mile of the CTF boundary.

A new underground telecommunications duct bank system will be required between the CTF complex buildings and to support future growth in the CTF complex. For estimating purposes, this system is assumed to have two 4 in. ducts for telecommunications, a 4 in. duct for the fire alarm network, a 4 in. duct for security systems, a 4 in. duct for other alarm and control cabling, and a 4 in. spare for a total of six 4 in. ducts. A manhole will be required at intervals of 300 ft and just outside each major building. This system will start at the CTF boundary manhole and extend throughout the CTF complex.

Grounding will be per TIA/EIA 607, "Commercial Building Grounding and Bonding Requirements for Telecommunications and NEC 800." A separate grounding electrode system will be provided near each building's telecommunications entrance point. This system will be bonded to the building's main electrical grounding electrode system at a single point. The bond point will be able to be inspected.

6.8.2 Facility Monitoring System

The FMS provides the CTF complex building with a alarm annunciation, status monitoring, and event reconstruction capability. Each CTF complex building will have a stand-alone system that reports back to the main CTF office building via the FMS network. There will be an FMS 19 in. color monitor at the entrance to each significant CTF complex building to provide status annunciation to the building users and emergency response personnel. The FMS will monitor the status of all building systems, BMS, safety parameters, and each loop/process safety parameter status.

It has been assumed that the FMS information pathways will be an Ethernet based network with distributed data acquisition and control (SCADA) using high-capacity cables, including fiber and copper as appropriate with a flexible horizontal distribution.

A FMS PC based terminal will be located in the supervisory control room.

6.8.3 Building Management System

The BMS will provide for safe and energy efficient operation of the CTF buildings by implementing a building energy management system. Each CTF complex building will have a stand-alone system that reports back to the CTF FMS via the FMS network.

It is assumed that BMS information pathways will be an Ethernet based network with distributed data acquisition and control (SCADA) using high capacity cables, including fiber and copper as appropriate, flexible horizontal distribution, and standardized jacks. The system will be coordinated with HVAC, water usage, lighting control, and electrical power metering requirements.

The BMS will include all control hardware and software necessary for complete direct digital control, including all modules, temperature sensors, smoke detectors, flow sensors, damper actuators, lighting controls, and any other items necessary for a complete system and sequence of control. The BMS will be a totally native building automation and control network control system based on a distributed logic control system. The operator's terminal, all global controllers, logic controllers, and all input/output devices will communicate using the protocols as defined in ANSI/ASHRAE Standard 135-1995, "BACnet."

A BMS PC-based terminal will be located in the supervisory control room.

6.8.4 Oxygen Monitoring System

The oxygen monitoring system will use sensors capable of measuring an atmospheric oxygen concentration of at least 0 to 25%. The system will have an independent adjustable low oxygen alarm for each channel. A key lockable maintenance alarm bypass switch will be provided at the central control station to prevent remote alarming during calibration and testing. A remote alarm testing switch will be provided at the central control station. The central control station will have a “Fault” alarm with a relay dry contact output for detection of sensor failure or other malfunctions. The BMS will monitor the Fault alarm. A remote white flashing beacon and audible warning horn will be provided near each sensor.

The oxygen monitoring system should be supplied by UPS power. The loss of line power to the system will cause a “Trouble” alarm at the FMS.

The analog value and alarm status of each Oxygen Monitoring channel will be monitored by the FMS to aid in incident reconstruction. Interfaces to the FMS will use acceptable isolation, such as dry contacts, to prevent failure of the FMS from interfering with the function of the oxygen monitoring system.

An oxygen monitoring system remote transmitter and remote beacon and horn will be provided within gas bottle rooms and other areas where oxygen deficient gas may accumulate. Additional locations may be required as determined by the Safety Analysis Report.

It is assumed the BMS will document the operation of each oxygen monitoring channel.

For planning purposes, it is assumed there will be six sensor/beacons per loop/process and 20 for the H2PS. The remote beacon and horn are assumed to be Edwards series 51 Adaptabeacon 51C-G5-20WH and the sensors are Delta-F.

6.8.5 Process Video System

The process video system provides capability of passing streaming life video images from various locations to monitors as Video Over Internet Protocol. The video system provides for monitoring actions within the facilities. Each of the high-resolution color cameras will be fed into video switchers that feed video digitizers that stream the video onto the video subnetwork. These cameras will have remote control zoom and pan tilt that is controlled via the network. The streaming video can then be selected and viewed at any of the monitors or recorded for later viewing. Multiple video sources may be accessed simultaneously from either local or remote locations.

For planning purposes it is assumed there will be six network color pan/tilt cameras per loop/process. Each set of loop/process cameras will feed into a video subnetwork and have independent digital video recorders..

6.8.6 Process E-Stop System

The process E-Stop system provides a means to stop a loop or process if an operator sees an unsafe problem. The E-Stop system will override the process control system and place the process in a safe shutdown mode. An E-Stop activation will effect only the observed loop/process, a master facility wide Master E-Stop will effect all loops and processes. The individual loop/process control rooms will have control over that loop/process. The Master E-Stop and all of the loop/process E-Stop inputs will be provided in the supervisory control rooms. The supervisory control room operator can stop any process via that processes E-Stop input. All E-Stop systems will be monitored by the FMS to aid in incident reconstruction. Interfaces to the FMS will use acceptable isolation, such as dry contacts, to prevent failure of the FMS from interfering with the function of the E-Stop system. The E-Stop system will be designed to ensure ease of maintenance and testing without unduly compromising the functionality of protected process equipment and will avoid single point and common mode failures. The E-Stop system will meet the requirements of NFPA 79, Section 7-6 and ANSI B11.19, Section 5.2 and 5.5.

The actuation of an E-Stop switch will NOT stop other activities only the equipment associated with that E-stop will be affected. This means that the E-Stop system must be configurable to a specific process.

For planning purposes, it is assumed there will be six network color pan/tilt cameras per loop/process. Each set of loop/process cameras will feed into a video subnetwork and have independent digital video recorders.

6.8.7 Paging System

The paging system provides for voice announcements to be made throughout the CTF facilities.

Each major CTF building will have a stand alone PA system and each building will support outdoor speakers within that buildings area. Smaller buildings will be fed from the nearest major building. Each system will have three inputs: a building only input, an all-call input, and a recorded voice announcement input. The PA system inputs will come through the telephone system. The system local and all-call inputs will be accessible from any telephone.

The PA will have sufficient number of speakers and power to provide 100% coverage throughout the facility with at least 10 dB above the local ambient noise level. Outside, horn type speakers will be provided. The PA speakers will operate from a 70.7v distribution amplifier and will have adjustable sound level at each speaker. Separate volume controls will be provided for each of the three input types. Each individual speaker will be adjustable for volume.

The PA amplifiers and interface equipment will be located in the telecommunications closets and will be powered by the UPS power system.

A network based PA system will be considered during final design.

6.8.8 Security System

The security system will detect security breaches at CTF and report those to the INL security force via an existing central alarm system. The security system will work in conjunction with the access control system.

A security video system provides capability of passing streaming life surveillance video images from various locations to monitors over a multiplexed system. The video system provides for monitoring actions within the facilities. Each of the high resolution color cameras will be fed into video switchers that feed video digitizers that stream the video onto the video subnetwork. These cameras will have remote control zoom and pan tilt that is controlled via the network. The streaming video then can be selected and viewed at any of the monitors or recorded for later viewing.

For planning purposes assume there will be a balanced magnetic detector door switch at each door of each major building, there will be four rooms in the two major buildings that have interior motion detectors. Each major CTF building will have a security multiplexer linked into a fiber optic security network, and there will be eight outside color pan/tilt/zoom cameras and four interior cameras per major building. Each camera will feed into a video subnetwork and will be recorded on digital video recorders.

A new multiple strand high capacity security fiber optic cable will be provided from the security rack in the main CTF telecommunications equipment room to the security facility at CFA. For estimating purposes this fiber is assumed to be a 24 strand cable (12 single-mode and 12 multimode) and the existing underground duct bank system is available at 100 ft from the CTF complex boundary. It is assumed that the central alarm system is located within 1 mile of the CTF boundary.

The security system will be powered from the UPS system and designed to support the loads for 8 hours without offsite power. The building security system will be powered by a battery backed (independent of the UPS) 24 Vdc power source. The security system will continue to function during a failure of the communications link to the central alarm system.

6.8.9 Access Control System

The access control system will limit entry to CTF buildings and certain rooms or areas, coordinate with the security system, report access attempts to the INL security force via the security system, and work in conjunction with the security system.

A central access control computer with access database will be provided in the CTF office building. The building access control system will be compatible with the existing INL Site Access Control system and the DOE picture badges with a magnetic strip. The system will use an The associated advanced processing controller will be located in the CTF office building main telecommunications room.

Card readers and 1,200 lb electromagnetic locks will be located at each specified (to be determined during the preliminary design) door.

The access control system will be powered from the UPS system and designed to support the loads for 8 hours without offsite power. It will be powered by a battery backed 24 Vdc power source that is independent of the UPS and will continue to function during a failure of the communications link to the advanced processing controller.

For estimating purposes, card readers and magnetic door locks will be installed on each outside personnel door of the major CTF buildings, six storage and equipment rooms within the CTF and the H2PS buildings, each of the control rooms, each telecommunications equipment rooms, and the security guard house.

6.9 Instrumentation and Control

6.9.1 Instrumentation

Requirements

CTF implementation philosophy describes independent test development loops. This is achieved when each loop has its own I&C equipment. Loop function determines the components in the loop and the I&C requirements for them.

The facility safety and experimental data collection will be separate systems that are isolated from the individual loop control systems.

The safety control system will implement the personnel and facility safety constraints. The safety system instruments will be commonly available, industry standard technology. Instrumentation of critical safety parameters will be monitored at two or more separate points. Safety instrument signals will be isolated if they are also used by the control and experiment systems. Safety instrument and control actions will be recorded with accuracy and time resolution appropriate for the safety function.

Safety control functions will be implemented in physically separate, dedicated control hardware. Failure of a single controller will not affect other safety controllers. In addition, UPS power will be supplied to all safety controllers.

6.9.2 Accuracy

Industry standard instruments will be used for safety and control functions. Monitoring of controlled processes for experimental data will be performed with instruments that provide the best accuracy and reliability for the given use. These instruments will have calibrations traceable to National Institute of Standards and Technology (NIST).

6.9.3 Reliability

Instruments will be supplied and calibrated to maximize CTF availability. Some points associated with long duration tests may require multiple instruments so that one can be removed for calibration.

All instrument data and control actions will be recorded in two separate locations. Data will be stored at the local controller human-machine interface and by a central data management system.

6.9.4 Physical Aspects

Instrumentation must support the temperatures, pressures, and flows specified for the CTF. Instrumentation will be designed to provide the maximum flexibility in terms of mounting, electrical and mechanical connections, servicing, and change-outs. Distance between input transducers and signal conditioning will be kept to a minimum.

6.9.5 Documentation

Methods and transducers will have documentation or acceptance testing that verifies their performance for the particular usage in the CTF. Requirements for signal conditioning, data storage and analysis, and calibration methods will be specified.

All instruments will be procured to meet the intent of NQA 1. The vendor will provide verification that the instruments meet the intent of NQA 1.

6.10 Data Management

6.10.1 Data Security

Information will be secured in accordance with the applicable requirements of the Federal Information Security Management Act, Publications 199 and 200 and supporting NIST Guidelines: SP 800-18, -30, -37, -53, -53A, -59, and -60.

The CTF data network architecture will implement the Secure Architecture Design shown in Figure 21.

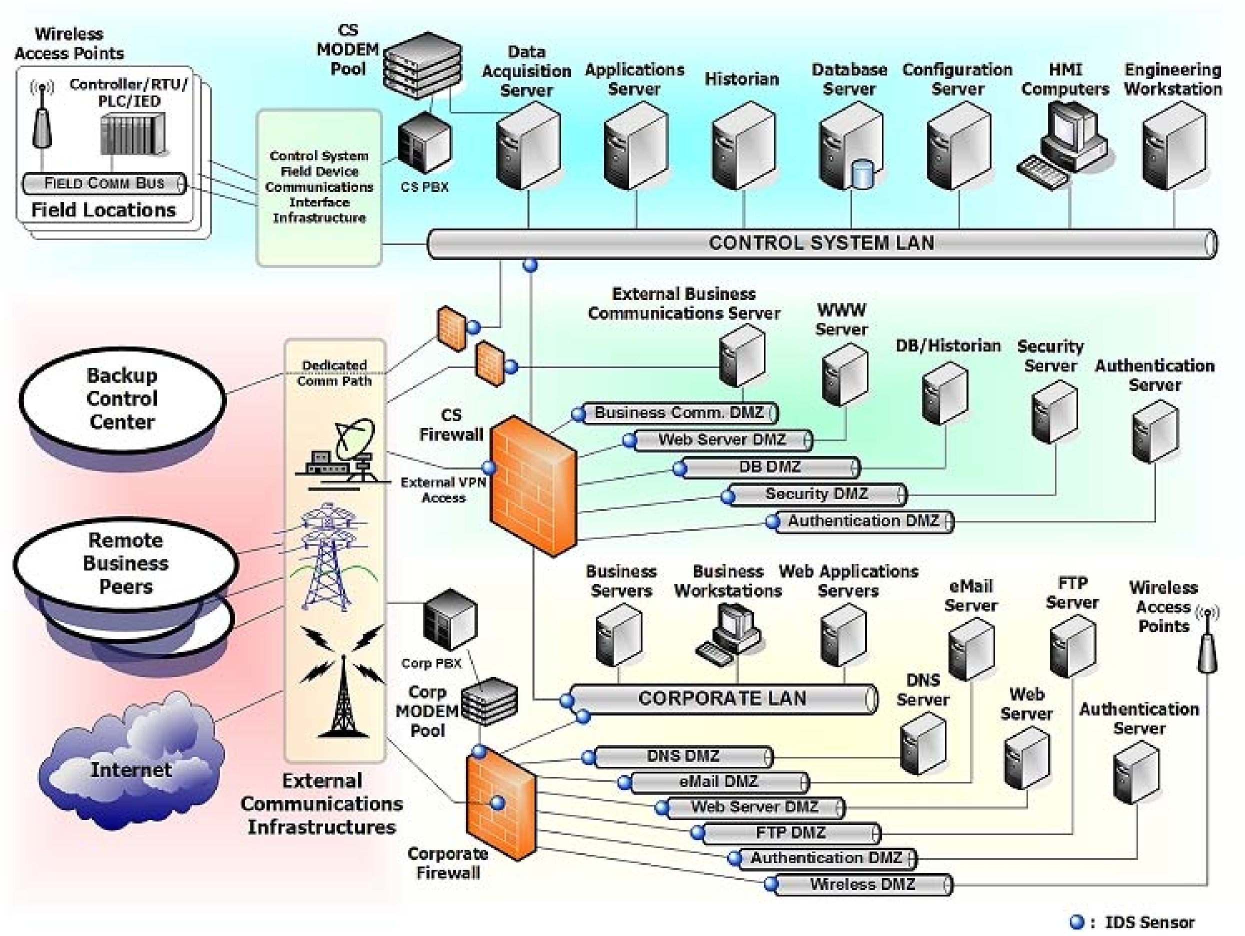


Figure 21. Secure architecture design.

Confidentiality

The data management system will be designed to ensure the information contained in the system is not disclosed to unauthorized individuals, processes, or devices. It must provide access control to maintain vendor and experiment data separation.

Experimental data and experimental data collection will be kept under access control to assure that instrument data and control signals associated with proprietary components are protected. This information protection will include assurance that a single failure cannot cause the loss of all data and that stored data cannot be modified (FIPS 113, 191, 200; IEEE 1619).

When no longer needed, as defined by the useful life of the data, the data stored on the system will be securely destroyed so that it cannot be recovered.

Integrity

The data management system will be designed to ensure that information has not been modified or deleted in an unauthorized manner. Data will be recorded with accurate time stamps and associated with a unique instrument identifier.

Availability

The data management system will be designed to ensure that the information stored on the system is accessible and useable upon demand by an authorized user in a timely and reliable manner according to the performance specification for the system. It may contain released experimental data and implement the proper level of access control to this data. It should include an offsite location that duplicates the storage of the streamed data.

The data management system will be designed to provide backup for all information stored on the system. Data will be archived after a set period of time but will be protected. Data storage systems will be reviewed and upgraded on a periodic basis, or as needed, to ensure that the data format and hardware required to retrieve data are still available and functioning. This may require resaving data to different storage media or maintaining hardware that can read and output the stored information.

6.10.2 Data Collection

Protocol

Industry standard protocols will be used. Different protocols will be kept to a minimum.

Network

A high capacity data network will connect the operator control station, control components, and instrument termination points. It will provide sufficient network ports with connections for instrumentation devices, data collection/control systems, and operator system access with substantial, at least double initial, additional bandwidth capacity and network ports.

The location and number of these portals will allow the ease of movement of instruments or instrument clusters without network disruptions or major restructuring.

All communication in the network will be protected from external interference and the network will maintain the data’s integrity.

All network components at the switch level and above will be self-checking, support system diagnostic, perform alternate routing, and be located in easily accessible areas that are suitably protected for the environment in which they are used.

6.10.3 Quality

The quality requirements of NQA1 will be applied to data collection and storage. All data will be completely traceable to the source, time, and method it was produced.

The sampling and compression of the data will be determined by the requirements for the instrument.

Instrumentation hardware and software for the data management system will be under configuration control per NQA1.

6.10.4 Capacity

The data storage system will be designed to store data from all of the instruments, control actions, and modeling for project specified time requirements.

The size of data storage depend on the number of instruments, the data bandwidth, and data granularity.

The data management system will be designed to accommodate new technologies in the transmission and storage of data. This may include the ability to add or change data transmission paths or technologies and data storage media or devices.

6.10.5 Data Access

A data access and reporting system will be provided to allow authorized users access to stored data. A method to access data subsets via an industry standard query language, such as SQL, will be provided. Access to high bandwidth data, such as video, will be provided in project-specified or industry-standard format.

6.11 Control Action/Response

6.11.1 Process Control

Control system will be capable of providing programmable control to the heaters, motors, and other actuators to implement the steady-state and transient temperature and flow profiles, as specified.

The control system will have the capability of responding to synthetic and sensor data, and utilize classical and intelligent control algorithms.

The control system will provide a safety shutdown input.

The CTF loop control systems will provide a means to allow experimenters to establish the loop temperature and flow profiles. Experimental systems placed in the CTF will provide monitor signals to the loop control so that the requested gas temperatures and flows can be provided. The transmission of these signals from the experimental system and the control loop values back to the experimental system will be implemented using industry standard field-bus protocol.

The control systems may provide a remote control capability for a limited range of temperatures, flows, and equipment operating levels.

The reliability of the control system hardware/software will have a defined lifetime that is consistent with the life-cycle requirements of the design.

6.11.2 Safety

The reliability of the control system hardware/software will consider the necessary response, as determined by the safety basis, and provide the capability to use independence and redundancy per industrial safety standards.

6.11.3 Reliability

The reliability of the control system hardware will have a defined lifetime that is consistent with the life-cycle requirements of the design. The life cycle of the control system hardware/software will consider the availability of technological advances.

The physical aspects of the control system will be consistent with the process environment.

The packaging of the control system hardware will be ergonomically designed for maintenance and replacement, and appropriate for the operating environment.

6.11.4 Equipment Protection

Facility will provide adequate cooling for all control and instrumentation components.

The control system will include all interlocks and control actions necessary to protect the controlled components. All control systems will be designed to fail in a safe manner.

The control system should include methods to assure maximum life for controlled components.

6.12 Human Data Interface

Operator displays and controls will be designed to human factors standards and to maintain situational awareness. Display of system safe operation parameters will take priority.

Discrete hardware control, such as shutdown switches, will be reserved for the safety system.

Experimental visualization and control may be incorporated into portions of the human interface.

6.12.1 Simulation Interface

A facility for plant operation simulations will be provided for operational pre-job planning, experimentation, and practice.

Operator virtual simulation and practice facilities will be provided.

7. PRELIMINARY HAZARD CATEGORIZATION

The CTF, together with the hydrogen production facility, will not involve the use of radioactive materials. The facility is therefore expected to be categorized as a non-nuclear, nonradiological facility. Significant quantities of certain chemicals and the associated hazards require that the project be evaluated from a safety standpoint early in the design process. These anticipated hazards are further identified in Table 5, which identifies the significant hazards associated with producing and storing hydrogen gas. Among other preventative and mitigative features identified in Table 5, it is recognized that a safe separation distance will be required between the hydrogen production facility and other existing INL facilities and future anticipated facilities, such as a HTGR. A previous study and detailed analysis was performed modeling the effects of an explosion of 100 kg of hydrogen. Separation distances were recommended of at least 110 m for a 100 kg bench-scale production facility. Other recommendations from that study include the use of blast barriers, offsite product compression and storage, inert co-axial piping, offsite control room location (for a nuclear plant), and below-ground placement of critical portions of the hydrogen production facility. The NGNP anticipates a 50 MW(t) facility that will produce hydrogen at the rate of 15 kg/min and have the capacity to store a 3-day production supply onsite. Storage of 65,000 kg of hydrogen presents potential for significant risks, which will be further evaluated as the program develops.

As the project design matures, this document will need to be revised and other safety documents and analyses will need to be generated. These supporting documents, other than operational procedures, will include, as appropriate, a Fire Hazard Analysis, Fire Safety Assessments, a preliminary documented safety analysis (PDSA), and a documented safety analysis (DSA) (DOE approval required) to supplement the INL's: standardized DSA, Hoisting and Rigging Plan, Engineering Design Files, Safe Work Permits, operational job safety analyses, and industrial hygiene exposure assessments prepared in accordance with the associated INL procedures.

This preliminary hazards analysis is a tool that will provide safety analysis and design teams with a frame of reference as their activities commence. It will identify potential hazards and initiators that should be considered as the design process begins and will continue to be considered through approval of the final DSA. Having a common frame of reference at the onset helps avoid potential late design modifications and will result in a safer facility.

The list of potential hazards identified in Table 6 is intended to be an outline for the development of a hazards assessment and facility safety basis documents. It incorporates experience and lessons-learned in other facility safety design and operations. The current stage of the conceptual design process does not require the detailed analysis of accidents. Analyses will be completed in conjunction with development of the PDSA. At this time, it is prudent to establish the thought processes necessary to develop accident scenarios for the PDSA.

Table 6. Preliminary hazards identified for the CTF and hydrogen production facility.

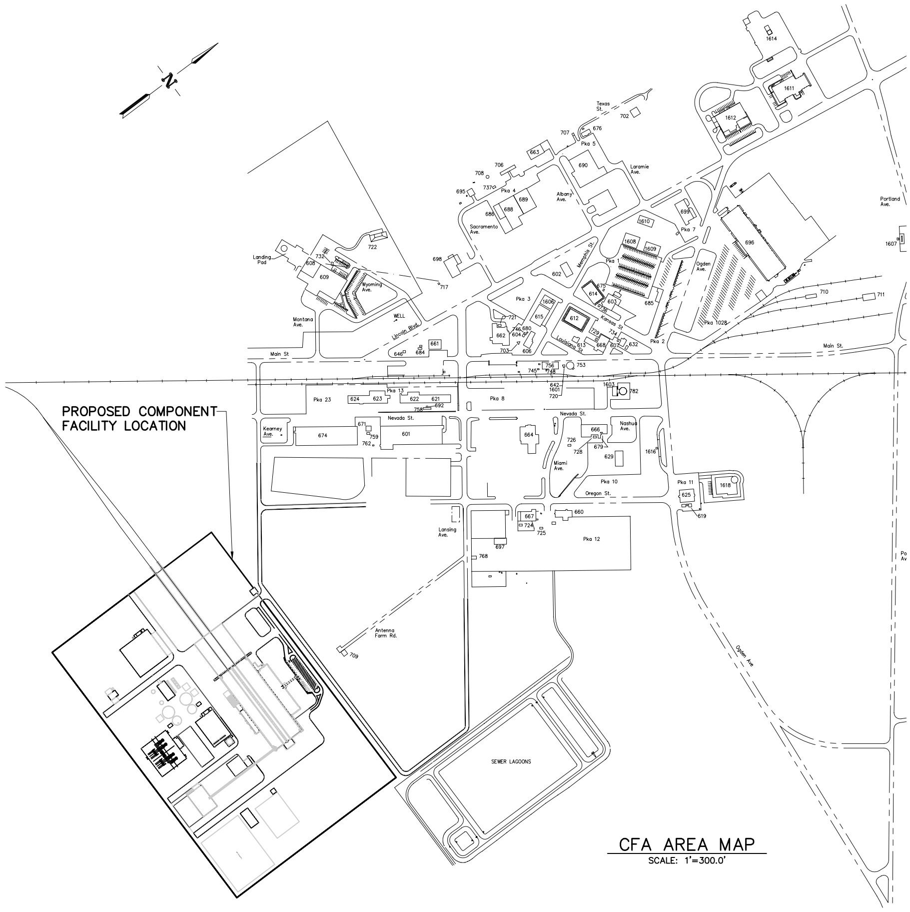
Hazard	Initiator	Location	Operation	Possible Consequences	Preventive Features	Mitigative Features
High temperature/ pressure helium gas	Breach in coolant system, over-pressurization rupture	CTF test loops	Facility operations, component testing	Damage to facility components, damage to test components, personnel burns, personnel asphyxiant	Equipment inspection and maintenance programs, employee training, facility design, surveillance program, operating procedures	Immediate worker evacuation, emergency response procedures, facility ventilation systems
Hydrogen	Breach in production vessels, breach in transport lines, breach in storage vessels, valve failure, tank or piping leakage	Hydrogen production facility and storage locations	Plant operation; hydrogen production and storage	Damage to facility, personnel asphyxiant, hydrogen fire, gas deflagration, detonation, explosion, pressure excursion	Facility design, limited personnel access, control ignition sources, hydrogen detection and alarm systems, facility exhaust ventilation, forced ventilation systems in enclosed areas, operating procedures, employee training, equipment inspection and maintenance programs, backflow prevention devices, safe siting location, use of an inert co-axial piping system for hydrogen distribution	Facility monitoring system, facility evacuation system, fire alarm systems, facility ventilation system, immediate worker evacuation, fire suppression systems, onsite fire department response
Sulfuric Acid – and other sulfur compounds as chemical intermediaries in hydrogen production	Loss of production vessel integrity	Hydrogen production facility	Plant operation – hydrogen production	Personnel injury, acid burns, violent acid-water reactions, severe burns	Robust reaction vessel design, employee training, system surveillance and maintenance programs, safe operating procedures	Onsite emergency response organization, emergency response procedures, spill containment equipment

Table 5. (continued).

Hazard	Initiator	Location	Operation	Possible Consequences	Preventive Features	Mitigative Features
High purity oxygen	Breach in production vessels, breach in transport lines, breach in storage vessels, valve failure, tank or piping leakage	Hydrogen production facility	Plant operation – hydrogen production	Strong oxidizer with fuels, reactant, toxic in high concentration	Facility design, limited personnel access, control ignition sources, detection and alarm systems, facility exhaust ventilation, forced ventilation systems in enclosed areas, operating procedures, employee training, equipment inspection and maintenance programs, backflow prevention devices, safe siting location	Facility monitoring system, facility evacuation system, facility ventilation system, immediate worker evacuation, fire suppression systems
Iodine and other iodine compounds as intermediaries in hydrogen production	Breach in production vessels, breach in transport lines, breach in storage vessels, valve failure, tank or piping leakage	Hydrogen production facility	Plant operation – hydrogen production	Chemical release to facility, personnel uptake hazard, severe burns	Robust reaction vessel design, employee training, system surveillance and maintenance programs, safe operating procedures	Onsite emergency response organization, emergency response procedures, spill containment equipment

Appendix A

Drawings



CFA AREA MAP

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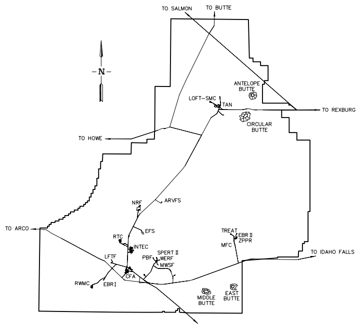

INL SITE MAP

SCALE: NONE

DRAWING INDEX

PAGE NO.	DWG NO.	SH NO.	REV	DRAWING TITLE
1		T–1		INL SITE MAP, CFA AREA MAP AND DRAWING INDEX
2		C–1		SITE PLAN
3		A–1		RENDERED IMAGE
4		A–2		RENDERED IMAGE
5		A–3		RENDERED IMAGE
6		A–4		CTF FLOOR PLAN
7		A–5		ADMINISTRATION SUPPORT FLOOR PLAN
8		A–6		HIGHBAY SECTIONS
9		P–1		TEST LOOPS SCHEMATIC
10		P–2		TDL1 SCHEMATIC
11		P–3		TDL2 SCHEMATIC
12		P–4		TDL3 SCHEMATIC
13		P–5		COMPONENT QUALIFICATION LOOP (CQL) SCHEMATIC
14		P–6		CIRCULATION TEST LOOP SCHEMATIC
15		P–7		CQL SCHEMATIC
16		P–8		TDL3 SCHEMATIC
17		P–9		CQL SCHEMATIC
18		E–1		CTF ONELINE DIAGRAM
19		E–2		CTF ONELINE DIAGRAM
20		E–3		HYDROGEN GENERATION FACILITY ONE–LINE DIAGRAM
21		E–4		WATER PROCESS FACILITY ONE–LINE DIAGRAM
22		IN–1		NETWORK OVERVIEW DIAGRAM
23		IN–2		TEST LOOP DATA FLOW DIAGRAM

REV	DATE	DESCRIPTION

REVISION HISTORY

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REQUESTER: **VJ BALLS**
RESP ENGR: **SL AUSTAD**
DESIGN:
DRAWN:
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

INL SITE MAP, CFA AREA MAP AND DRAWING INDEX

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG–
REV
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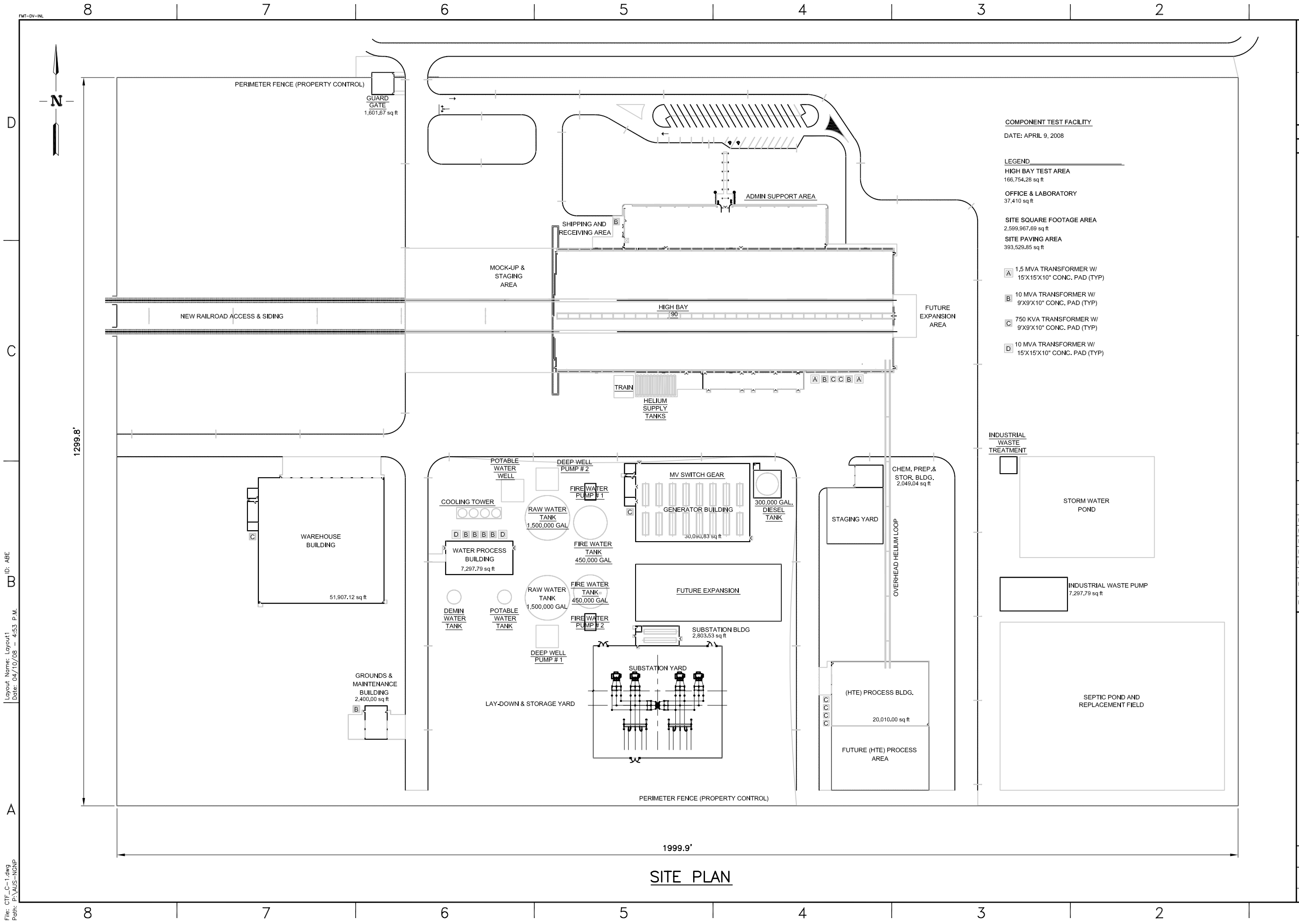

COMPONENT TEST FACILITY

DATE: APRIL 9, 2008

LEGEND

HIGH BAY TEST AREA
166,754.28 sq ft

OFFICE & LABORATORY
37,410 sq ft

SITE SQUARE FOOTAGE AREA
2,599,967.69 sq ft

SITE PAVING AREA
393,529.85 sq ft

A 1.5 MVA TRANSFORMER W/ 15'X15'X10" CONC. PAD (TYP)

B 10 MVA TRANSFORMER W/ 9'X9'X10" CONC. PAD (TYP)

C 750 KVA TRANSFORMER W/ 9'X9'X10" CONC. PAD (TYP)

D 10 MVA TRANSFORMER W/ 15'X15'X10" CONC. PAD (TYP)

SITE PLAN

2

REV	DATE	DESCRIPTION

REVISION HISTORY

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FOR DRAWING INDEX SEE DRAWING NO.
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RESP ENGR:	LE GUILLEN
DESIGN:	BL BLAKLEY
DRAWN:	BL BLAKLEY
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

SITE PLAN

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D
DWG-
REV

SHEET C-1

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FMT-DV-INL

3

LOOKING SOUTHEAST FROM THE ENTRANCE

RENDERED IMAGE

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REVISION HISTORY		

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RESP ENGR:	SL AUSTAD
DESIGN:	BL BLAKLEY
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PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

RENDERED IMAGE

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01MF3				081

INDEX CODE NUMBER

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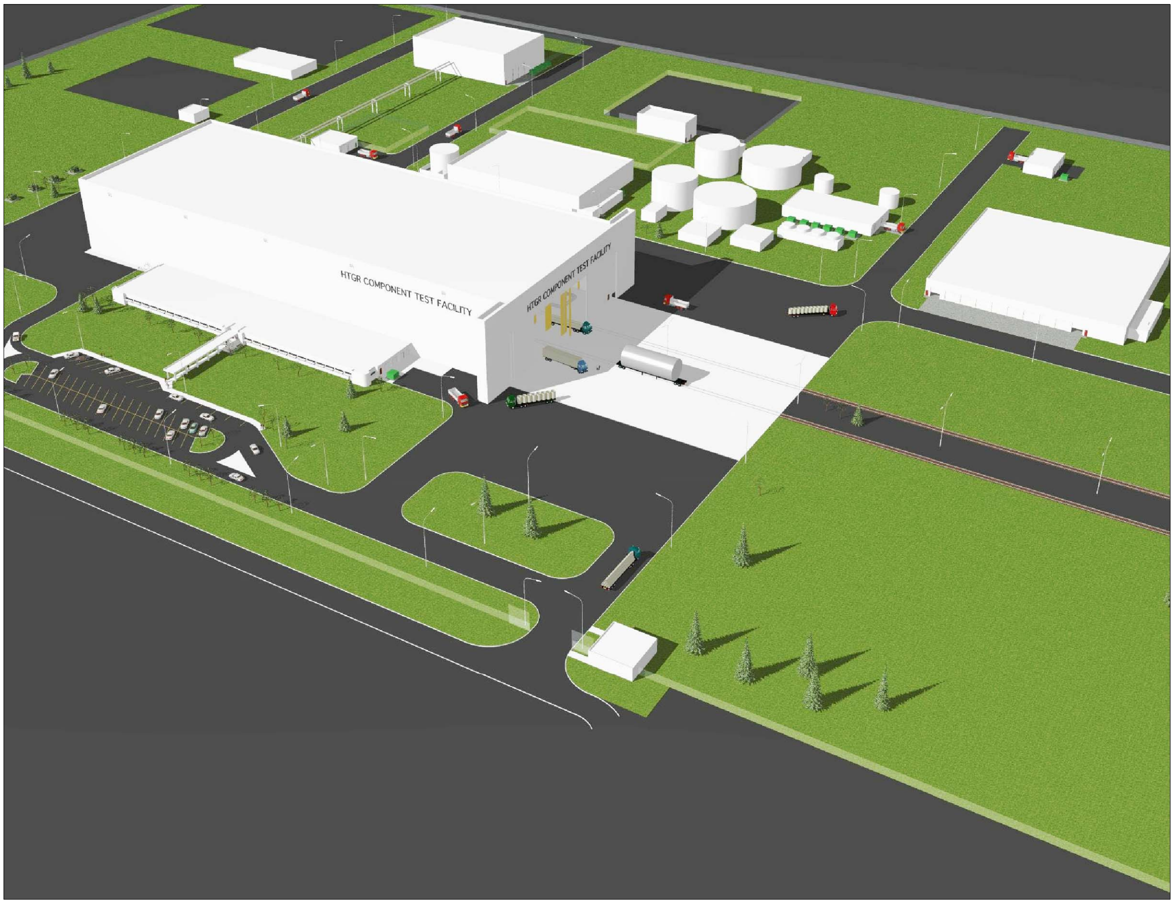

LOOKING SOUTHEAST FROM ABOVE

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PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

RENDERED IMAGE

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

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FMT-DV-INL

LOOKING SOUTH

RENDERED IMAGE

REV	DATE	DESCRIPTION

REVISION HISTORY

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FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

RENDERED IMAGE

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INDEX CODE NUMBER

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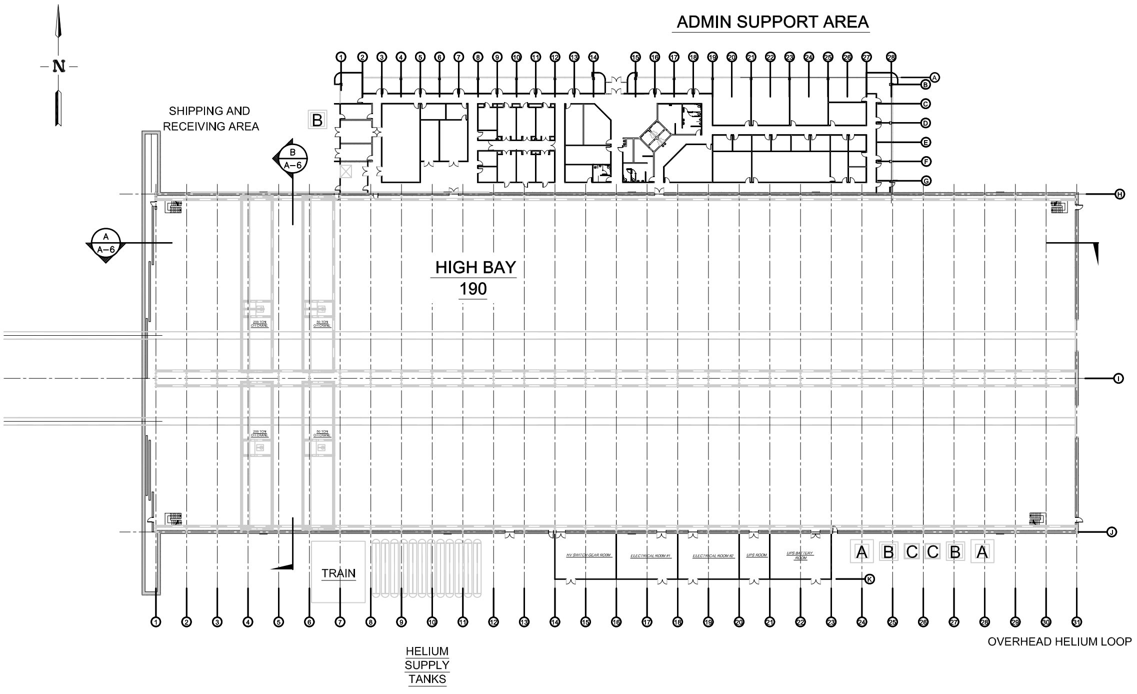

CTF FLOOR PLAN

REV	DATE	DESCRIPTION

REVISION HISTORY

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PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

CTF FLOOR PLAN

CAGE CODE	AREA	TYPE	CL	ORIG
01MF3				081

INDEX CODE NUMBER

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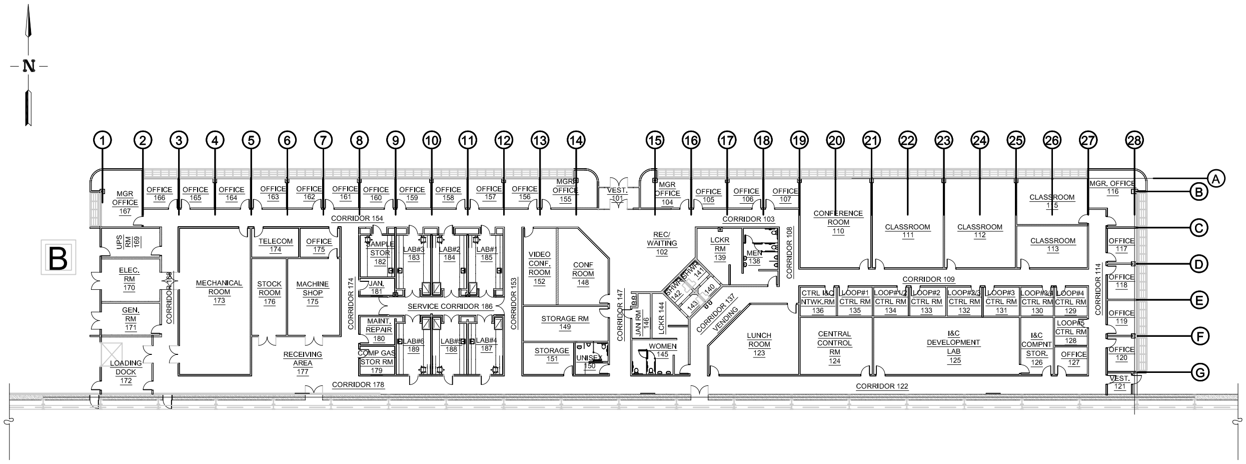

ADMINISTRATION SUPPORT

FLOOR PLAN

REV	DATE	DESCRIPTION

REVISION HISTORY

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VERTICAL SCALE N/A

FOR DRAWING INDEX SEE DRAWING NO. T-1

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RESP ENGR: **SL AUSTAD**
DESIGN: **BL BLAKLEY**
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PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

ADMINISTRATION SUPPORT FLOOR PLAN

CAGE CODE 01MF3
INDEX CODE NUMBER AREA TYPE CL ORIG 081
SIZE D DWG-
REV
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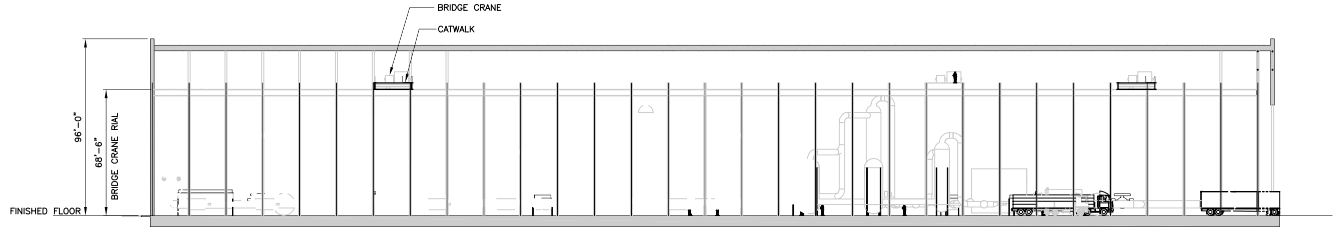

HIGHBAY

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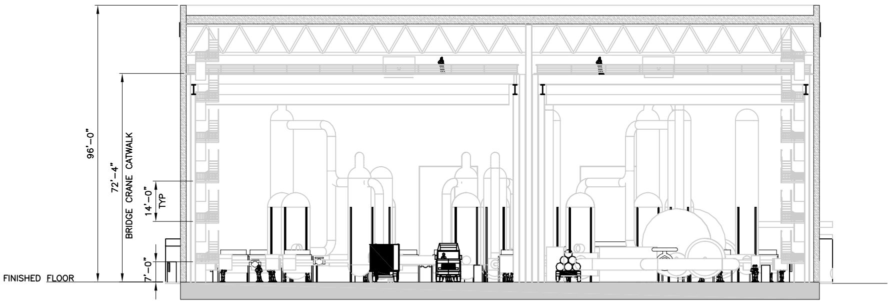

HIGHBAY

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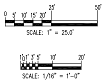

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DESIGN: **BL BLAKLEY**
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PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

ADMINISTRATION SUPPORT FLOOR PLAN

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG– REV

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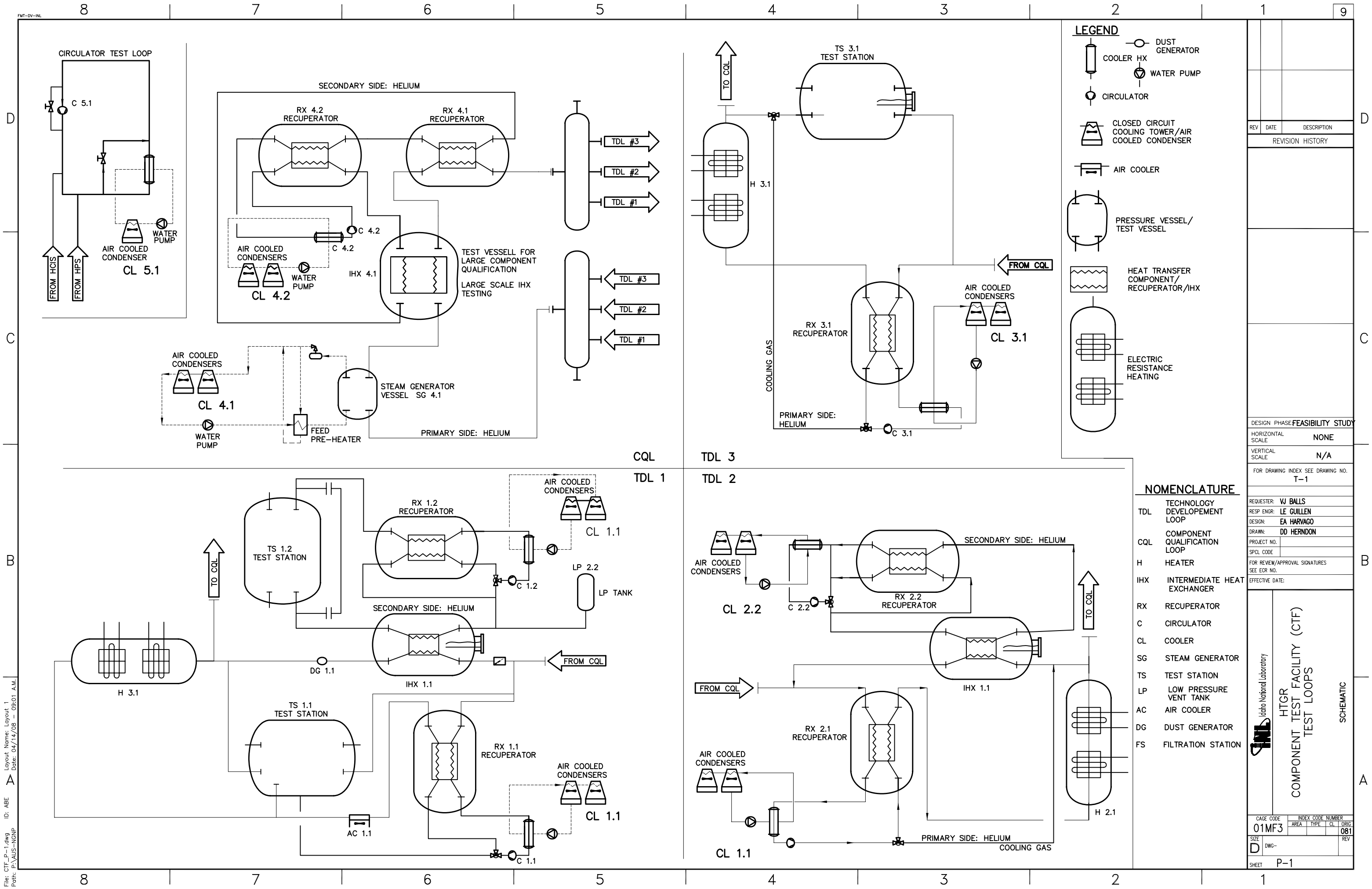

NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
CL	COOLER
SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

DESIGN PHASE:	FEASIBILITY STUDY
HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO. T-1

REQUESTER:	VJ BALLS
RESP ENGR:	LE GUILLEN
DESIGN:	EA HARVAGO
DRAWN:	DD HERNDON
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
TEST LOOPS

SCHEMATIC

CAGE CODE	AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG– REV

SHEET P-1

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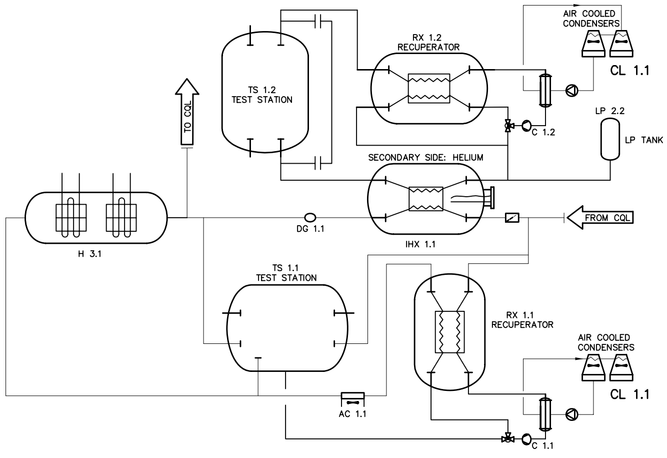
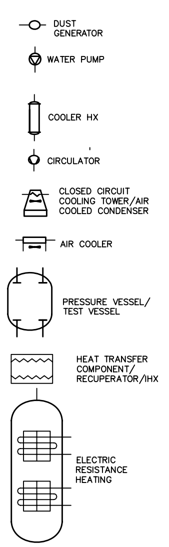


TDL 1

LEGEND



NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
CL	COOLER
SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

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PROJECT NO.	
SPCL CODE	
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	
EFFECTIVE DATE:	

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
TDL 1

SCHEMATIC

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

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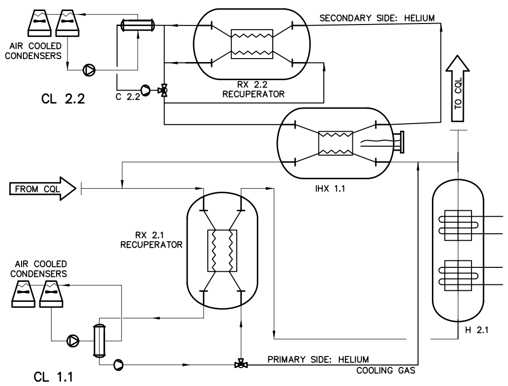
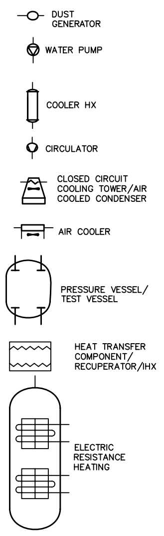


TDL 2

LEGEND



NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
CL	COOLER
SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

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DESIGN: **EA HARVAGO**
DRAWN: **DD HERNDON**
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
TDL 2

SCHEMATIC

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
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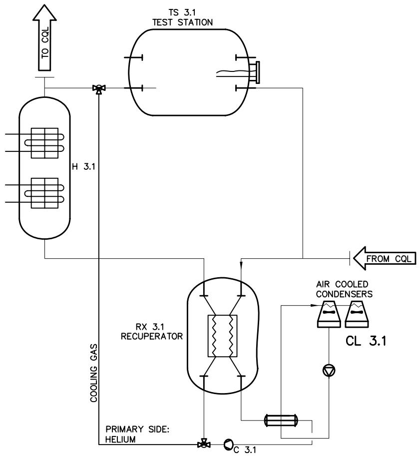
SIZE D DWG-
REV
SHEET P-3



TDL 3

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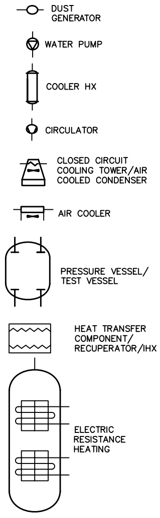

NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
CL	COOLER
SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: **FEASIBILITY STUDY**
HORIZONTAL SCALE: NONE
VERTICAL SCALE: N/A
FOR DRAWING INDEX SEE DRAWING NO. T-1

REQUESTER: **VJ BALLS**
RESP ENGR: **LE GUILLEN**
DESIGN: **EA HARVAGO**
DRAWN: **DD HERNDON**
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY
TDL 3

SCHEMATIC

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG– REV
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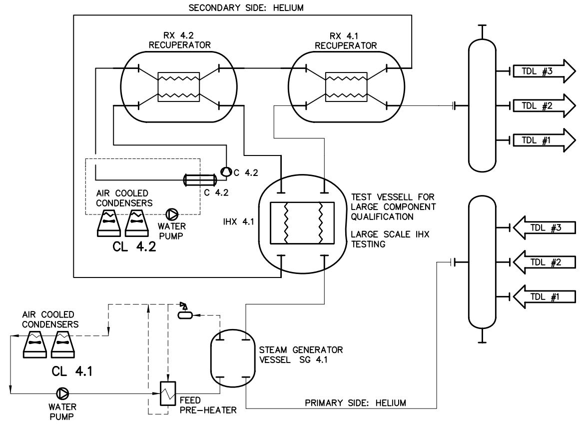

COMPONENT QUALIFICATION LOOP (CQL)

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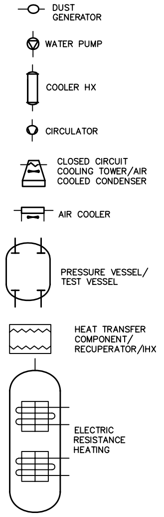

NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
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LP	LOW PRESSURE VENT TANK
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DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE:	FEASIBILITY STUDY
HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A
FOR DRAWING INDEX SEE DRAWING NO.	T-1
REQUESTER:	VJ BALLS
RESP ENGR:	LE GUILLEN
DESIGN:	EA HARVAGO
DRAWN:	DD HERNDON
PROJECT NO.	
SPCL CODE	
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.	
EFFECTIVE DATE:	

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
COMPONENT QUALIFICATION LOOP (CQL)

SCHEMATIC

CAGE CODE	AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

SHEET P-5

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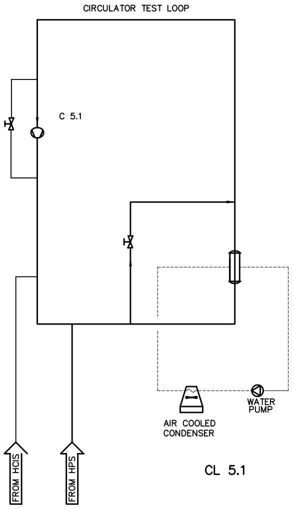
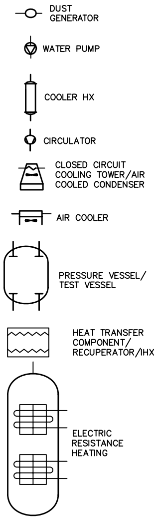
FMT-DV-INL

14



CIRCULATION TEST LOOP

LEGEND



NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
CL	COOLER
SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: **FEASIBILITY STUDY**

HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO. T-1

REQUESTER:	VJ BALLS
RESP ENGR:	LE GUILLEN
DESIGN:	EA HARVAGO
DRAWN:	DD HERNDON
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
CIRCULATION TEST LOOP

SCHEMATIC

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

SHEET P-6

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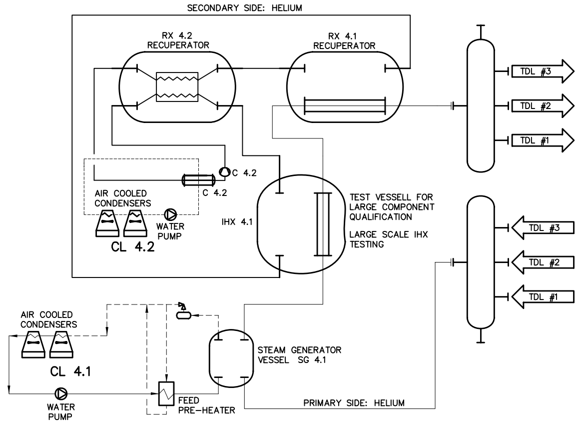
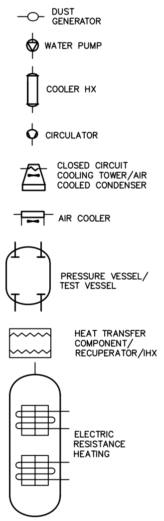


CQL

LEGEND



NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
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SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: FEASIBILITY STUDY

HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO.
T-1

REQUESTER:	VJ BALLS
RESP ENGR:	LE GUILLEN
DESIGN:	EA HARVAGO
DRAWN:	DD HERNDON
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
CQL

SCHEMATIC

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

SHEET P-7

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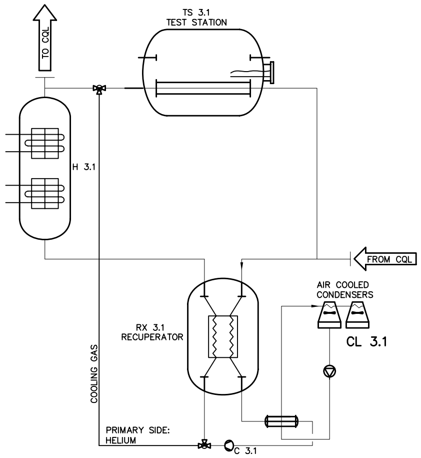
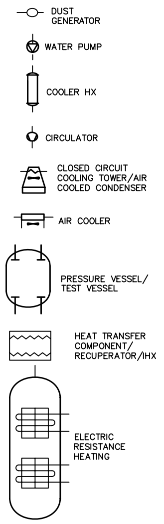


TDL 3

LEGEND



NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
CL	COOLER
SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: **FEASIBILITY STUDY**
HORIZONTAL SCALE: NONE
VERTICAL SCALE: N/A
FOR DRAWING INDEX SEE DRAWING NO. T-1
REQUESTER: **VJ BALLS**
RESP ENGR: **LE GUILLEN**
DESIGN: **EA HARVAGO**
DRAWN: **DD HERNDON**
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
TDL 3

SCHEMATIC

CAGE CODE 01MF3
INDEX CODE NUMBER: AREA | TYPE | CL | ORIG 081
SIZE D
DWG-
REV
SHEET P-8

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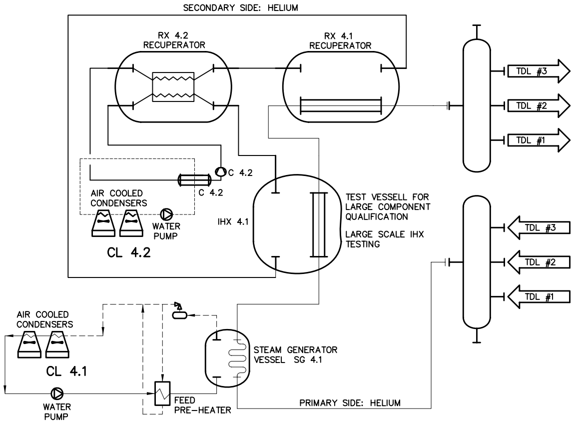
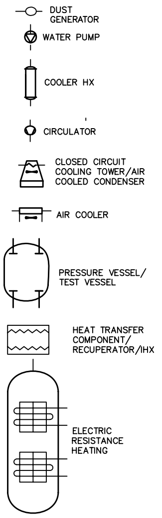
Date: 04/14/08 - 09:01 A.M.



CQL

LEGEND



NOMENCLATURE

TDL	TECHNOLOGY DEVELOPEMENT LOOP
CQL	COMPONENT QUALIFICATION LOOP
H	HEATER
IHX	INTERMEDIATE HEAT EXCHANGER
RX	RECUPERATOR
C	CIRCULATOR
CL	COOLER
SG	STEAM GENERATOR
TS	TEST STATION
LP	LOW PRESSURE VENT TANK
AC	AIR COOLER
DG	DUST GENERATOR
FS	FILTRATION STATION

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE:	FEASIBILITY STUDY
HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO.
T-1

REQUESTER:	VJ BALLS
RESP ENGR:	LE GUILLEN
DESIGN:	EA HARVAGO
DRAWN:	DD HERNDON
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
CQL

SCHEMATIC

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

SHEET P-9

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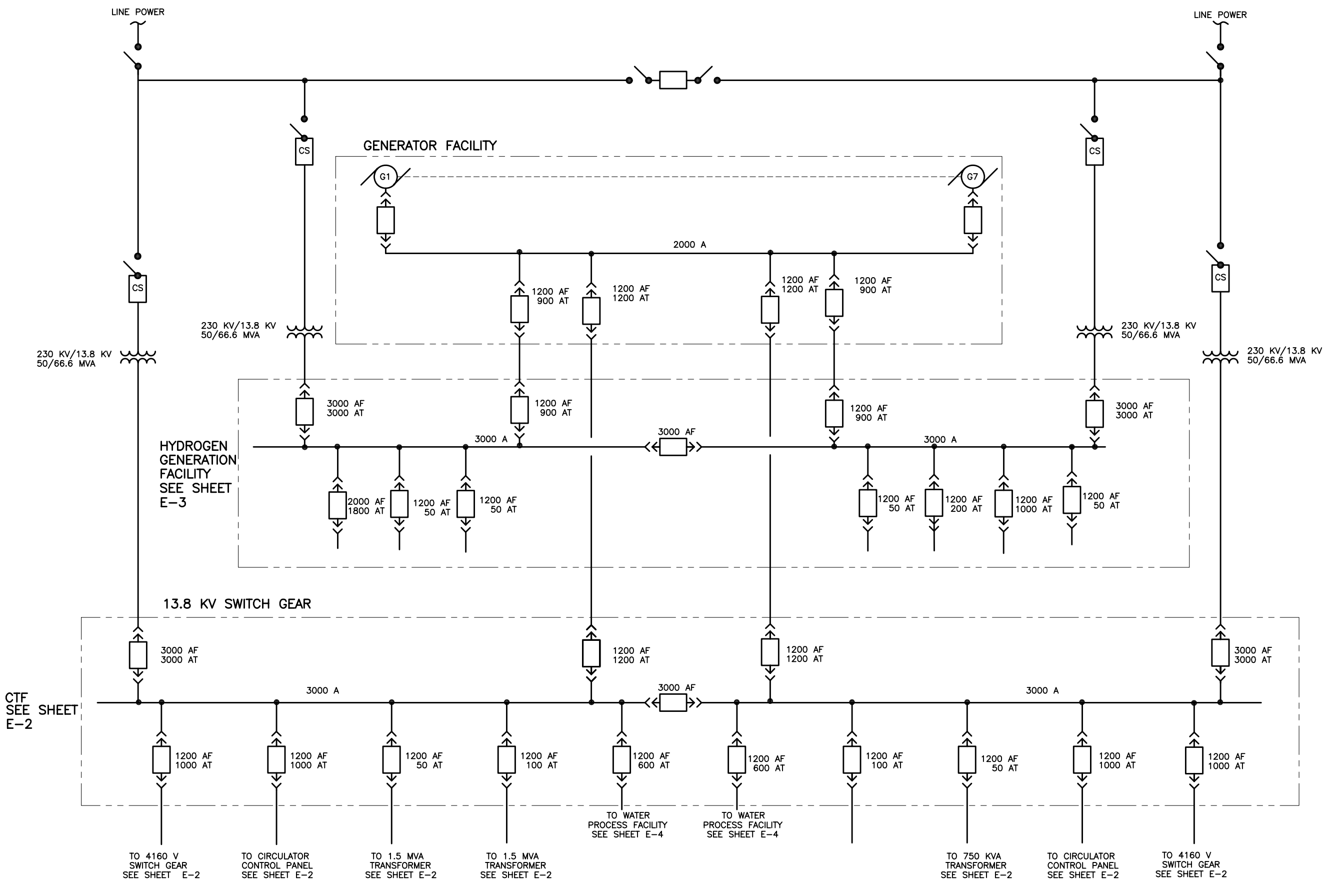

CTF ONE LINE DIAGRAM

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: **FEASIBILITY STUDY**

HORIZONTAL SCALE: NONE

VERTICAL SCALE: N/A

FOR DRAWING INDEX SEE DRAWING NO. T-1

REQUESTER: **VJ BALLS**

RESP ENGR: **DS FERGUSON**

DESIGN: **JD ZOLYNSKI / BL COWLEY**

DRAWN: **DD HERNDON**

PROJECT NO.

SPCL CODE

FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

CTF ONE LINE DIAGRAM

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

SHEET E-1

FMT-DV-INL

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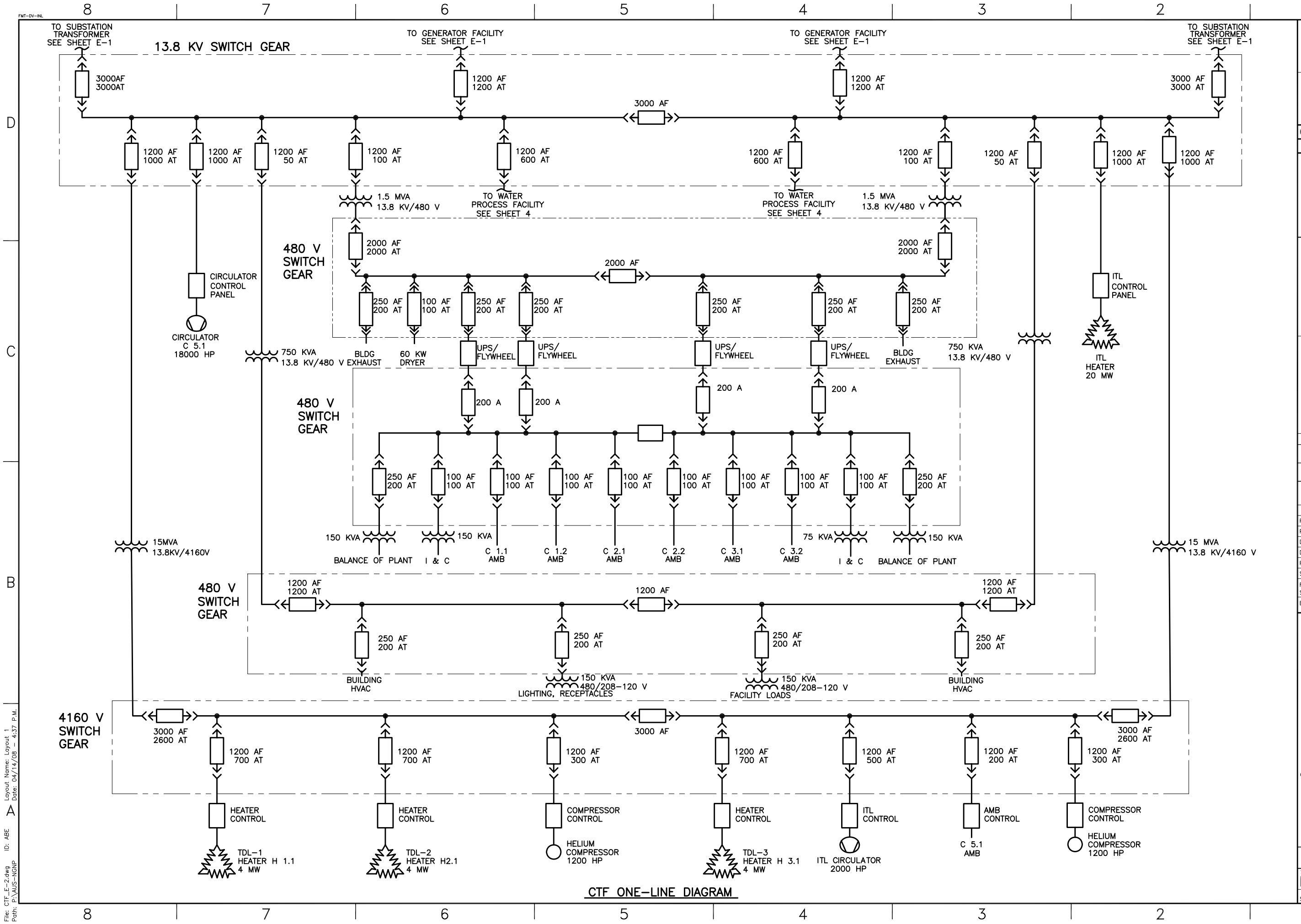

CTF ONE-LINE DIAGRAM

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: FEASIBILITY STUDY

HORIZONTAL SCALE NONE

VERTICAL SCALE N/A

FOR DRAWING INDEX SEE DRAWING NO. T-1

REQUESTER: VJ BALLS
RESP ENGR: DS FERGUSON
DESIGN: JD ZOLYNSKI / DL COWLEY
DRAWN: DD HERNDON
PROJECT NO.
SPCL CODE
FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

CTF ONE-LINE DIAGRAM

CAGE CODE 01MF3
INDEX CODE NUMBER AREA TYPE CL ORIG 081
SIZE D DWG-
REV
SHEET E-2

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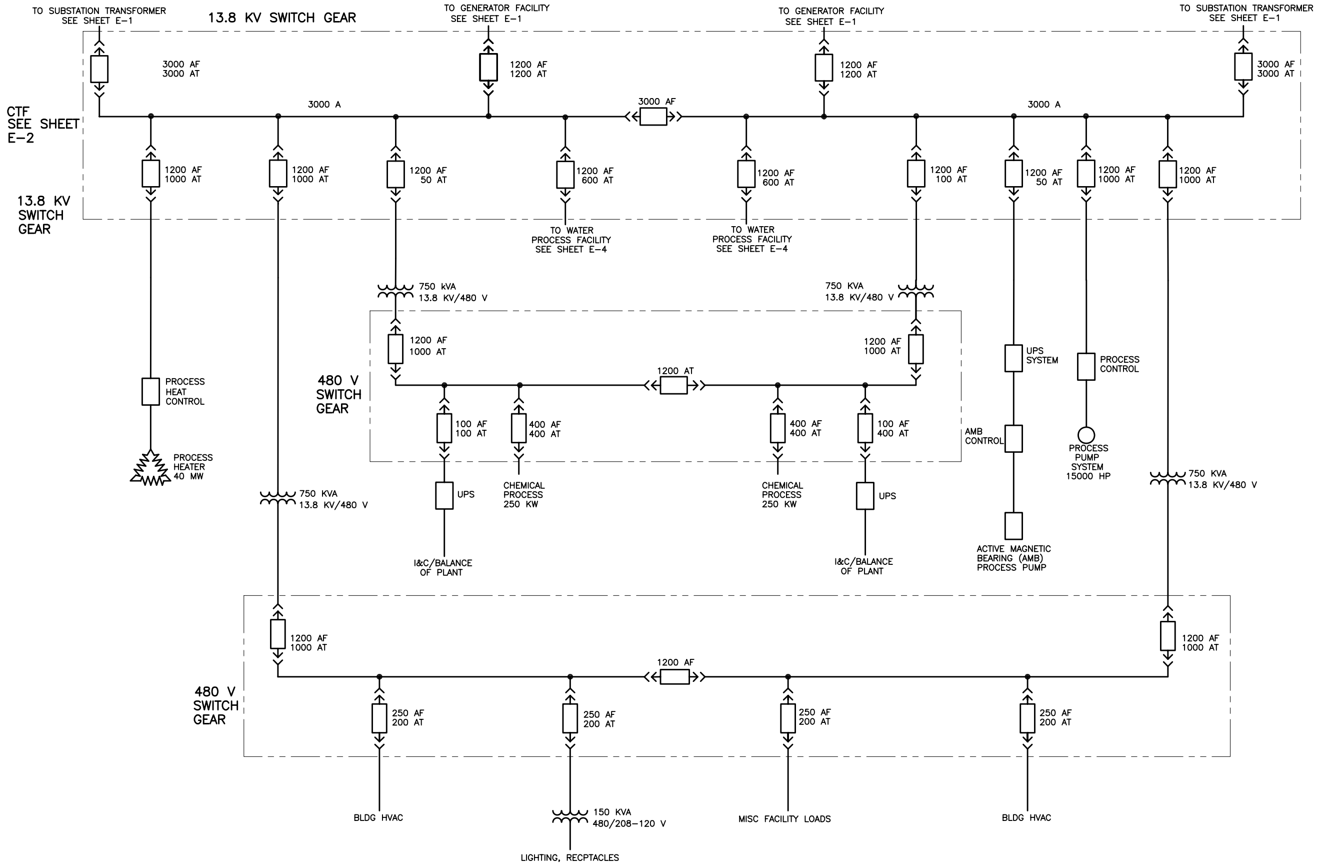

HYDROGEN GENERATION FACILITY ONE-LINE DIAGRAM

20

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: FEASIBILITY STUDY

HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO. T-1

REQUESTER:	VJ BALLS
RESP ENGR:	DS FERGUSON
DESIGN:	JD ZOLYNSKI / BL COWLEY
DRAWN:	DD HERNDON
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
HYDROGEN GENERATION FACILITY

HYDROGEN GENERATION FACILITY ONE-LINE DIAGRAM

CAGE CODE	AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

SHEET E-3

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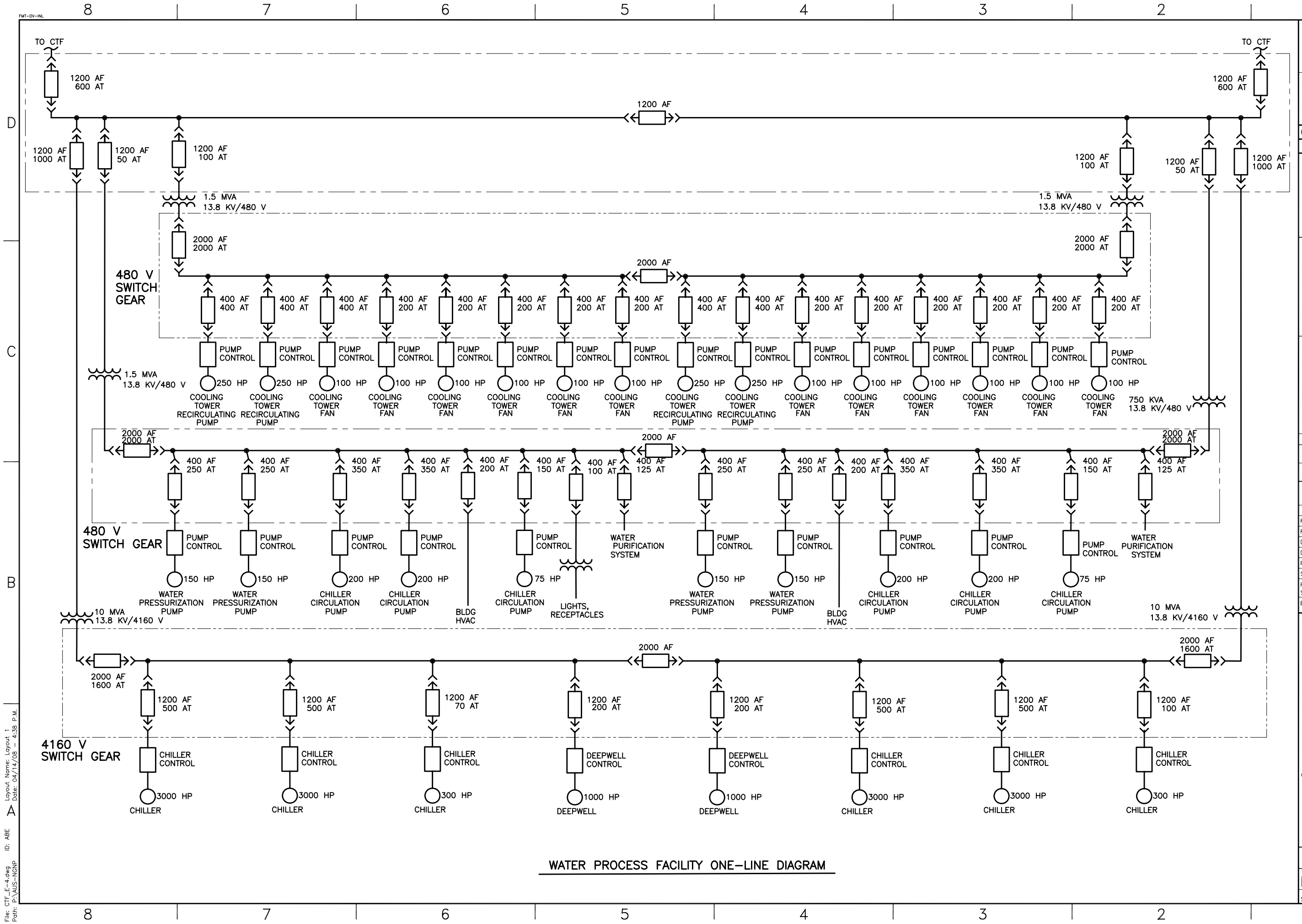
FMT-DV-INL

21



WATER PROCESS FACILITY ONE-LINE DIAGRAM

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: **FEASIBILITY STUDY**

HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO.
T-1

REQUESTER:	**VJ BALLS**
RESP ENGR:	**DS FERGUSON**
DESIGN:	**JD ZOLYNSKI / BL COWLEY**
DRAWN:	**DD HERNDON**
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO.

EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)
WATER PROCESS FACILITY

WATER PROCESS FACILITY ONE-LINE DIAGRAM

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG– REV

SHEET E-4

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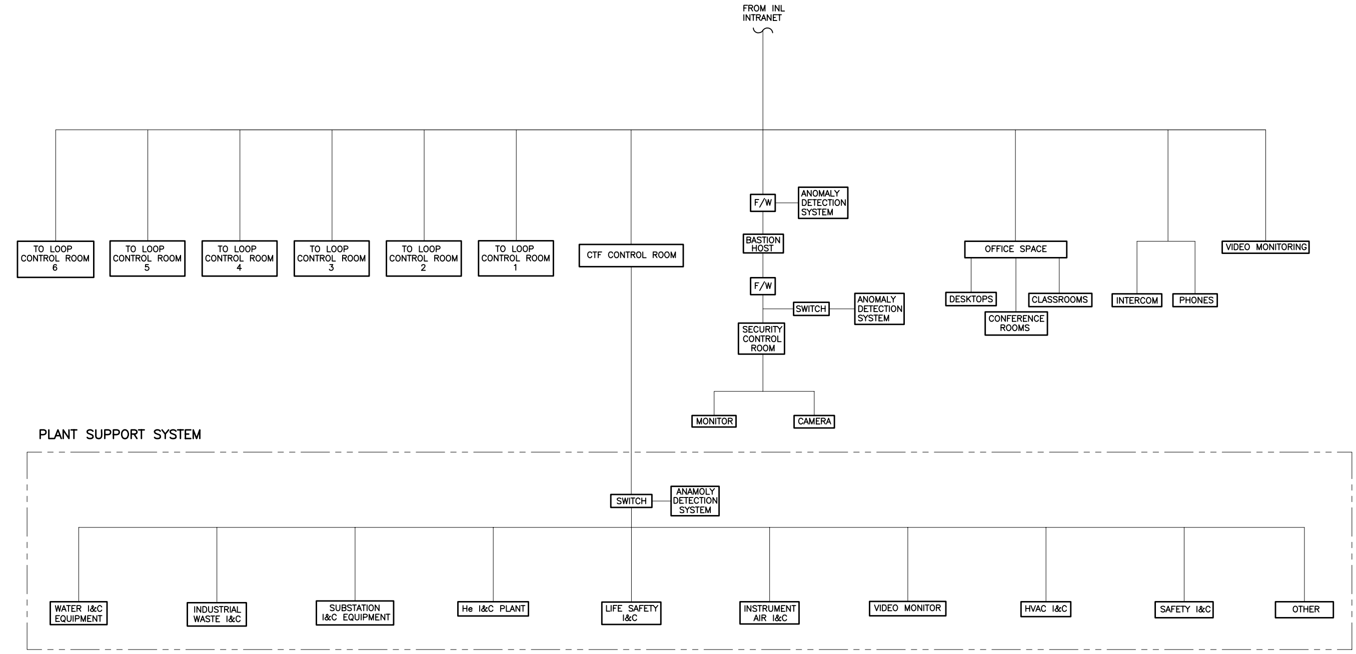
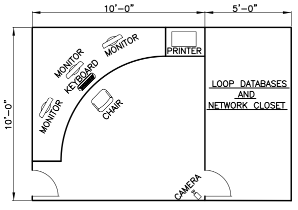


NETWORK OVERVIEW DIAGRAM



TYPICAL CONTROL ROOM LAYOUT

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: **FEASIBILITY STUDY**

HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO.
T-1

REQUESTER:	**VJ BALLS**
RESP ENGR:	**DS FERGUSON**
DESIGN:	**DM PACE**
DRAWN:	**DD HERNDON**
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

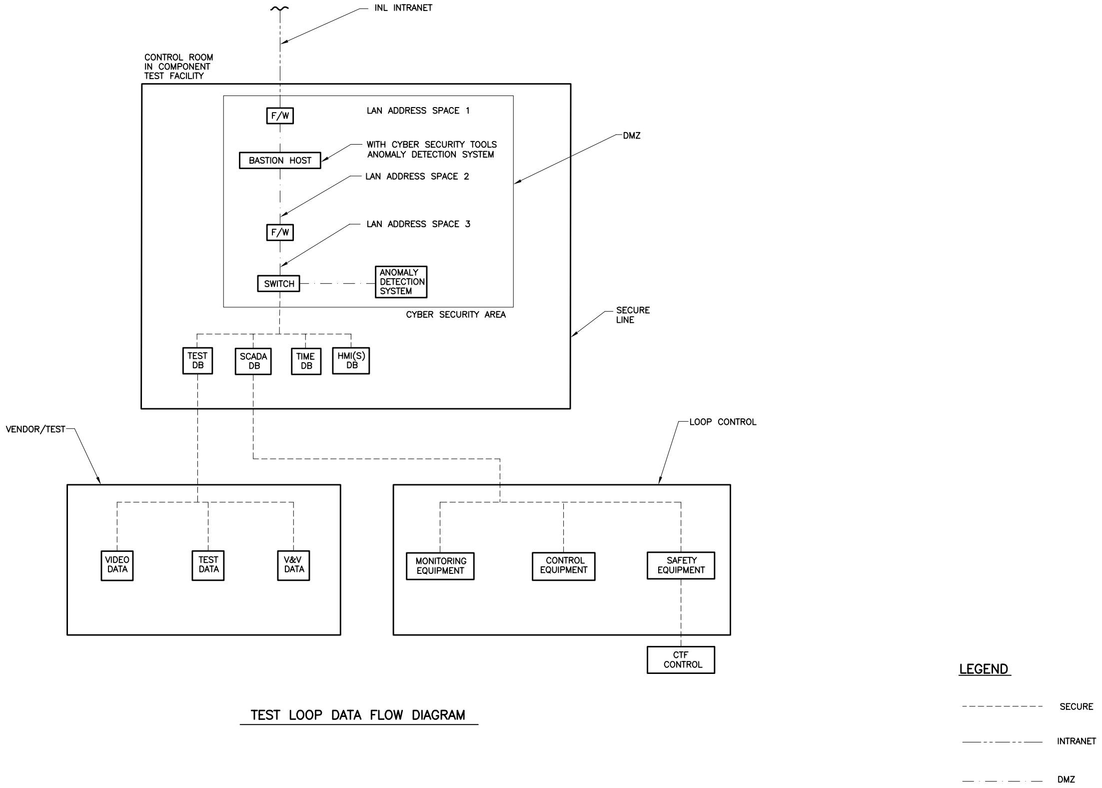
NETWORK OVERVIEW DIAGRAM

CAGE CODE	INDEX CODE NUMBER AREA	TYPE	CL	ORIG
01MF3				081

SIZE D DWG- REV

SHEET IN-1

File: CTF_IN-1.dwg ID: ABE Layout Name: Layout 1
Path: P:\AUS-NGNP Date: 04/14/08 - 09:02 A.M.



TEST LOOP DATA FLOW DIAGRAM

REV	DATE	DESCRIPTION

REVISION HISTORY

DESIGN PHASE: **FEASIBILITY STUDY**

HORIZONTAL SCALE	NONE
VERTICAL SCALE	N/A

FOR DRAWING INDEX SEE DRAWING NO.
T-1

REQUESTER:	**VJ BALLS**
RESP ENGR:	**DS FERGUSON**
DESIGN:	**DM PACE**
DRAWN:	**DD HERNDON**
PROJECT NO.	
SPCL CODE	

FOR REVIEW/APPROVAL SIGNATURES SEE ECR NO.
EFFECTIVE DATE:

Idaho National Laboratory

HTGR
COMPONENT TEST FACILITY (CTF)

TEST LOOP DATA FLOW DIAGRAM

CAGE CODE	AREA	TYPE	CL	ORIG
01MF3				081

SIZE D
DWG–
REV
SHEET IN-2

File: CTF_IN-2.dwg
Path: P:\AUS-NGNP
ID: ABE
Layout Name: Layout 1
Date: 04/14/08 – 3:25 P.M.

Appendix B

Electrical Load List

Appendix B

Electical Load Estimate

DSFerguson 04/03/2008 15:13PM

CTF Full-Scale Loop
Electrical Power Estimate

Rev 6 Addressed Reviewer Comments
Rev 7 Enabled iterative solving for circular Reference at cell F129,
Rev 8 Changed CQL

																					Concurrent	
Bldg	Area		Helium Flow kg/s	Load	MW(t)	Flow - gpm	MWe w/Eff	MWe	Operating Voltage	Source	Concurrent	Concurrent MWe	Gross Motor HP	$PF=\frac{MW}{MVA}$ PF	Expected Load MVA	Design Factor	Design MVA	MVA Sum	Concurrent MVA	MWe Eff Losses (CTF Bldg)	MWe Eff Losses (H2PS Bldg)	MWe Eff Losses (Water Bldg)
CTF	TDL - 1	Primary Loop (WEC Pg D.5)	2	Process Heater H1.1	*4.00*		4.08	4.66	4160	NC	1	33.82		100%	4.08	100%	4.08	4.76	40.70	0.08		
CTF				Circulator Motor C1.1	*0.20*		0.22		480	C	1		297	90%	0.25	100%	0.25			0.02		
CTF				Circulator AMB C1.1			0.02		480	U	1			90%	0.03	100%	0.03			0.00		
CTF				Process Heat Reject into Bldg							1									2.60		
WPB				Chiller Comp (Cooler CL 1.1)	*1.60*		0.27		4160	C	1		357	80%	0.33	100%	0.33					0.27
WPB				Chiller Pump		1092	0.01		4160	C	1		17	80%	0.02	100%	0.02					0.01
Tower				Tower Fans	1.60		0.02		480	C	1		25	80%	0.02	100%	0.02					
Tower				Tower Circ Pump		910	0.02		480	C	1		24	80%	0.02	100%	0.02					
WPB				Deep Well Pump		35	0.01		4160	C	1		15	80%	0.01	100%	0.01					Outside
CTF		Secondary Loop (WEC Pg D.6)	2	Circulator Motor C1.2	*0.20*		0.22	0.66	480	C	1		297	90%	0.25	100%	0.25	0.79		0.02		
CTF				Circulator AMB C1.2			0.02		480	U	1			90%	0.03	100%	0.03			0.00		
CTF				Process Heat Reject into Bldg							1									-1.80		
WPB				Chiller Comp (Cooler CL 1.2)	*2.00*		0.33		4160	C	1		447	80%	0.42	100%	0.42					0.33
WPB				Chiller Pump		1365	0.02		4160	C	1		22	80%	0.02	100%	0.02					0.02
Tower				Tower Fans	2.00		0.02		480	C	1		31	80%	0.03	100%	0.03					
Tower				Tower Circ Pump		1137	0.02		480	C	1		30	80%	0.03	100%	0.03					
WPB				Deep Well Pump		44	0.01		4160	C	1		19	80%	0.02	100%	0.02					Outside
CTF	TDL - 2	Primary Loop (WEC Pg D.8)	2	Process Heater H2.1	*4.00*		4.08	4.66	4160	NC	1			100%	4.08	100%	4.08	4.76		0.08		
CTF				Circulator Motor C2.1	*0.20*		0.22		480	C	1		297	90%	0.25	100%	0.25			0.02		
CTF				Circulator AMB C2.1			0.02		480	U	1			90%	0.03	100%	0.03			0.00		
CTF				Process Heat Reject into Bldg							1									2.60		
WPB				Chiller Comp (Cooler CL 2.1)	*1.60*		0.27		4160	C	1		357	80%	0.33	100%	0.33					0.27
WPB				Chiller Pump		1092	0.01		4160	C	1		17	80%	0.02	100%	0.02					0.01
Tower				Tower Fans	1.60		0.02		480	C	1		25	80%	0.02	100%	0.02					
Tower				Tower Circ Pump		910	0.02		480	C	1		24	80%	0.02	100%	0.02					
WPB				Deep Well Pump		35	0.01		4160	C	1		15	80%	0.01	100%	0.01					Outside
CTF		Secondary Loop (WEC Pg D.9)	2	Circulator Motor C2.2	*0.20*		0.22	0.70	480	C	1		297	90%	0.25	100%	0.25	0.84		0.02		
CTF				Circulator AMB C2.2			0.02		480	U	1			90%	0.03	100%	0.03			0.00		
CTF				Process Heat Reject into Bldg							1									-2.00		
WPB				Chiller Comp (Cooler CL 2.2)	*2.20*		0.37		4160	C	1		492	80%	0.46	100%	0.46					0.37
WPB				Chiller Pump		1501	0.02		4160	C	1		24	80%	0.02	100%	0.02					0.02
Tower				Tower Fans	2.20		0.03		480	C	1		34	80%	0.03	100%	0.03					
Tower				Tower Circ Pump		1251	0.02		480	C	1		33	80%	0.03	100%	0.03					
WPB				Deep Well Pump		48	0.02		4160	C	1		20	80%	0.02	100%	0.02					Outside
CTF	TDL - 3	Primary Loop (WEC Pg D.11)	2	Process Heater H3.1	*4.00*		4.08	4.66	4160	NC	1			100%	4.08	100%	4.08	4.76		0.08		
CTF				Circulator Motor C3.1	*0.20*		0.22		480	C	1		297	90%	0.25	100%	0.25			0.02		
CTF				Circulator AMB C3.1			0.02		480	U	1			90%	0.03	100%	0.03			0.00		
CTF				Process Heat Reject into Bldg							1									2.60		
WPB				Chiller Comp (Cooler CL 3.1)	*1.60*		0.27		4160	C	1		357	80%	0.33	100%	0.33					0.27
WPB				Chiller Pump		1092	0.01		4160	C	1		17	80%	0.02	100%	0.02					0.01
Tower				Tower Fans	1.60		0.02		480	C	1		25	80%	0.02	100%	0.02					

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CTF Full-Scale Loop
Electrical Power Estimate

Rev 6 Addressed Reviewer Comments
Rev 7 Enabled iterative solving for circular Reference at cell F129,
Rev 8 Changed CQL

													Gross Motor	$PF=\frac{MW}{MVA}$	Expected Load					Concurrent		
Bldg	Area		Helium Flow kg/s	Load	MW(t)	Flow - gpm	MWe w/Eff	MWe	Operating Voltage	Source	Concurrent	Concurrent MWe	HP	PF	MVA	Design Factor	Design MVA	MVA Sum	Concurrent MVA	MWe Eff Losses (CTF Bldg)	MWe Eff Losses (H2PS Bldg)	MWe Eff Losses (Water Bldg)
Tower				Tower Circ Pump		910	0.02		480	C	1		24	80%	0.02	100%	0.02					
WPB				Deep Well Pump		35	0.01		4160	C	1		15	80%	0.01	100%	0.01					Outside
CTF		Secondary Loop (WEC assumed)	2	Circulator Motor C3.2	*0.20*		0.22	0.70	480	C	0		297	90%	0.25	100%	0.25	0.84		0.02		
CTF				Circulator AMB C3.2			0.02		480	U	0			90%	0.03	100%	0.03			0.00		
CTF				Process Heat Reject into Bldg	-2.00						0									0.00		
WPB				Chiller Comp (Cooler CL 3.2)	*2.20*		0.37		4160	C	0		492	80%	0.46	100%	0.46					0.00
WPB				Chiller Pump		1501	0.02		4160	C	0		24	80%	0.02	100%	0.02					0.00
Tower				Tower Fans	2.20		0.03		480	C	0		34	80%	0.03	100%	0.03					
Tower				Tower Circ Pump		1251	0.02		480	C	0		33	80%	0.03	100%	0.03					
WPB				Deep Well Pump		48	0.02		4160	C	0		20	80%	0.02	100%	0.02					Outside
CTF		Circulator Loop (WEC D.15)	159.6	Circulator Motor C5.1	*12.40*		13.74	17.80	13800	NC	0		18418	90%	15.27	125%	19.08	23.95		0.00		
CTF				Circulator AMB C5.1			1.53		480	U	0			90%	1.70	100%	1.70			0.00		
CTF				Process Heat Reject into Bldg							0									0.00		
WPB				Chiller Comp (Cooler CL 5.1)	*12.40*		2.07		4160	NC	0		2770	80%	2.58	100%	2.58					0.00
WPB				Chiller Pump		8462	0.10		4160	NC	0		135	80%	0.13	100%	0.13					0.00
Tower				Tower Fans	12.40		0.15		480	NC	0		194	80%	0.18	100%	0.18					Outside
Tower				Tower Circ Pump		7052	0.14		480	NC	0		187	80%	0.17	100%	0.17					Outside
WPB				Deep Well Pump		271	0.09		4160	NC	0		115	80%	0.11	100%	0.11					Outside
CTF	CQL	Large Component Qual Loop	16.7				—	19.80	—	—	1	19.80						19.96	19.96			
CTF				Heater	*18.00*		18.37		13800	NC	1			100%	18.37	100%	18.37			0.37		
CTF				Circulator Motor	*1.16*		1.29		4160	C	1			90%	1.43	100%	1.43			0.13		
CTF				Circulator AMB			0.14		480	U	1			90%	0.16	100%	0.16			0.01		
CTF				Process Heat Reject into Bldg	11.56						1									11.56		
WPB		Component Qual Loop Primary		Water Treatment/Demineralizer		34.4	0.01	2.31	480	NC	0		15	80%	0.01	100%	0.01	2.78				0.00
CTF				Steam Gen (SG 4.1)	*11.20*						0											
CTF				Process Heat Reject into Bldg	*6.40*						0									0.00		
WPB				Chiller Comp (Cooler CL 4.1)	*4.80*		0.80		4160	C	0		1072	80%	1.00	100%	1.00					0.00
WPB				Chiller Pump		3276	0.04		4160	C	0		52	80%	0.05	100%	0.05					0.00
Tower				Tower Fans	*4.80*		0.06		480	C	0		75	80%	0.07	100%	0.07					Outside
Tower				Tower Circ Pump		2730	0.05		480	C	0		73	80%	0.07	100%	0.07					Outside
WPB				Deep Well Pump		105.1	0.03		4160	C	0		45	80%	0.04	100%	0.04					Outside
CTF		Component Qual Loop Secondary		Circulator Motor (C4.2)	*0.60*		0.66		4160	C	0		891	90%	0.74	100%	0.74			0.00		
CTF				Circulator AMB			0.07		480	U	0			90%	0.08	100%	0.08			0.00		
CTF				Process Heat Reject into Bldg	*0.14*						0									0.00		
WPB				Chiller Comp (Cooler 4.2)	2.80		0.47		4160	C	0		626	80%	0.58	100%	0.58					0.00
WPB				Chiller Pump		1911	0.02		4160	C	0		30	80%	0.03	100%	0.03					0.00
Tower				Tower Fans	2.80		0.03		480	C	0		44	80%	0.04	100%	0.04					Outside
Tower				Tower Circ Pump		1592	0.03		480	C	0		42	80%	0.04	100%	0.04					Outside
WPB				Deep Well Pump		61	0.02		4160	C	0		26	80%	0.02	100%	0.02					Outside
WPB	Process Heat Application	Hydrogen Production(Estimate for SI at 50 MW(t))	41.75	Water Purifier/Treatment		*15*	0.00	57.51	480	C	0	9.10	7	80%	0.01	100%	0.01	61.72	9.93			0.00
H2PS				Process Heating	*45.00*		45.92		13800	NC	0			98%	46.86	100%	46.86				0.00	
H2PS				Process Pumping	*2.50*		2.77		13800	C	0		3713	90%	3.08	125%	3.85				0.00	
H2PS				Chem Process		*5*																
H2PS				Chem Process Support (2.5%)			*0.06*		480	C	0			98%	0.06	100%	0.06				0.00	
H2PS				Other Loads - Pumps etc			0.00		480	NC	0		0	90%	0.00	100%	0.00				0.00	
H2PS				Process Heat Reject into Bldg																	0.00	
WPB				Chiller Comp	42.75		7.13		4160	C	0		9551	80%	8.91	100%	8.91					0.00
WPB				Chiller Pump		29173	0.35		4160	C	0		465	80%	0.43	100%	0.43					0.00

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CTF Full-Scale Loop
Electrical Power Estimate

Rev 6 Addressed Reviewer Comments
Rev 7 Enabled iterative solving for circular Reference at cell F129,
Rev 8 Changed CQL

Bldg	Area		Helium Flow kg/s	Load	MW(t)	Flow - gpm	MWe w/Eff	MWe	Operating Voltage	Source	Concurrent	Concurrent MWe	Gross Motor HP	$PF=\frac{MW}{MVA}$ PF	Expected Load MVA	Design Factor	Design MVA	MVA Sum	Concurrent MVA	Concurrent MWe Eff Losses (CTF Bldg)	MWe Eff Losses (H2PS Bldg)	MWe Eff Losses (Water Bldg)
Tower				Tower Fans	42.75		0.50		480	C	0		670	80%	0.63	100%	0.63					
Tower				Tower Circ Pump		24311	0.48		480	C	0		646	80%	0.60	100%	0.60					
WPB				Deep Well Pump		952	0.30		4160	C	0		405	80%	0.38	100%	0.38					Outside
WPB		Hydrogen Production (Estimate for Electrolysis)	|	Water Purifier/Treatment		*19*	0.01	9.10	480	C	1		8	80%	0.01	100%	0.01	9.93				0.01
H2PS				Process Heater	*1.11*		1.13		4160	NC	1			98%	1.16	100%	1.16				0.02	
H2PS				Electrolysis Unit		*6.34*	*5.10*		13800	NC	1			98%	5.20	100%	5.20				5.10	
H2PS				Sweep Gas Compressors			*1.33*		4160	C	1		1782	80%	1.66	100%	1.66				1.33	
H2PS				Other Loads - Pumps etc 10%			0.11		480	C	1		152	90%	0.13	100%	0.13				0.11	
H2PS				Process Heat Reject into Bldg																	0.00	
WPB				Chiller Comp	6.90		1.15		4160	C	1		1543	80%	1.44	100%	1.44					1.15
WPB				Chiller Pump		4712	0.06		4160	C	1		75	80%	0.07	100%	0.07					0.06
Tower				Tower Fans	6.90		0.08		480	C	1		108	80%	0.10	100%	0.10					
Tower				Tower Circ Pump		3927	0.08		480	C	1		104	80%	0.10	100%	0.10					
WPB				Deep Well Pump		172	0.05		4160	C	1		73	80%	0.07	100%	0.07					Outside
WPB	Balance of Plant (BOP)	HPS (1% of TDL-1, TDL-2, TDL-3 & Circ)	0.10	Water Purifier/Treatment		*0*	*0.00*	0.06	480	C	1	13.58	0	80%	0.00	100%	0.00	0.08	16.32			0.00
CTF				Dryer	*0.00*		0.00		480	C	1			100%	0.00	100%	0.00					
CTF				Helium Compressors			*0.04*		4160	C	1		58	80%	0.05	100%	0.05					
CTF				Other Loads - Pumps etc 10%			0.00		480	C	1		6	90%	0.01	100%	0.01					
WPB				Chiller Comp	0.05		0.01		4160	C	1		11	80%	0.01	100%	0.01					0.01
WPB				Chiller Pump		35	0.00		4160	C	1		1	80%	0.00	100%	0.00					0.00
Tower				Tower Fans	0.05		0.00		480	C	1		1	80%	0.00	100%	0.00					
Tower				Tower Circ Pump		29	0.00		480	C	1		1	80%	0.00	100%	0.00					
WPB				Deep Well Pump		1	0.00		4160	C	1		0	80%	0.00	100%	0.00					Outside
CTF		Other Support Bldg Loads (Eng Estimate)	|	Other Loads - CTF Bldgs etc			1.80	13.52	480	NC	1			90%	*2.00*	100%	2.00	16.24		1.80		
H2PS				Other Loads - H2PS Bldgs etc			0.90		480	NC	1			90%	*1.00*	100%	1.00				0.90	
WPB				Other Loads - WPB Bldgs etc			0.45		480	NC	1			90%	*0.50*	100%	0.50					0.45
Ware				Other Loads - Warehouse Bldg etc			*0.78*		480	NC	1			90%	0.87	100%	0.87					
Other				Other Loads - Other Bldgs etc			0.45		480	NC	1			90%	*0.50*	100%	0.50					
CTF				I&C System			0.05		480	U	1			90%	0.06	100%	0.06			0.05		
H2PS				I&C System			0.05		480	U	1			90%	0.06	100%	0.06				0.05	
WPB				I&C System			0.01		480	U	1			90%	0.01	100%	0.01					0.01
CTF				Cntrl Rm Sim/Computer Center			0.15		120/208	U	1			90%	0.17	100%	0.17			0.15		
CTF				Security			0.01		120/208	U	1			90%	0.01	100%	0.01			0.01		
H2PS				Security			0.01		120/208	U	1			90%	0.01	100%	0.01				0.01	
WPB				Security			0.01		120/208	U	1			90%	0.01	100%	0.01					0.01
CTF				Fire Alarm			0.01		120/208	U	1			90%	0.01	100%	0.01			0.01		
H2PS				Fire Alarm			0.01		120/208	U	1			90%	0.01	100%	0.01				0.01	
WPB				Fire Alarm			0.01		120/208	U	1			90%	0.01	100%	0.01					0.01
CTF				Building Management Sys (BMS)			0.01		120/208	U	1			90%	0.01	100%	0.01			0.01		
H2PS				Building Management Sys (BMS)			0.01		120/208	U	1			90%	0.01	100%	0.01				0.01	
WPB				Building Management Sys (BMS)			0.01		120/208	U	1			90%	0.01	100%	0.01					0.01
WPB				Chiller Comp - CTF Bldg + Inside Eff Loss	18.49		3.08		4160	C	1		4130	80%	3.85	100%	3.85					3.08
CTF				Other Air Exhuaster	-4.37		0.07		480	C	1		94	80%	0.09	100%	0.09					
WPB				Chiller Comp - H2PS Bldg + Inside Eff Loss	7.54		1.26		4160	C	1		1685	80%	1.57	100%	1.57					1.26
H2PS				Other Air Exhuaster	-0.11		0.00		480	C	1		2	80%	0.00	100%	0.00					
WPB				Chiller Comp - WPB Bldg + Inside Eff Loss	12.17		2.03		4160	C	1		2719	80%	2.54	100%	2.54					2.03
WPB				Other Air Exhuaster	9.99		0.16		480	C	1		216	80%	0.20	100%	0.20					
WPB				Chiller Pump		29825	0.35		4160	C	1		476	80%	0.44	100%	0.44					0.35

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CTF Full-Scale Loop
Electrical Power Estimate

Rev 6 Addressed Reviewer Comments
Rev 7 Enabled iterative solving for circular Reference at cell F129,
Rev 8 Changed CQL

Bldg	Area	Helium Flow kg/s	Load	MW(t)	Flow - gpm	MWe w/Eff	MWe	Operating Voltage	Source	Concurrent	Concurrent MWe	Gross Motor HP	$PF=\frac{MW}{MVA}$ PF	Expected Load MVA	Design Factor	Design MVA	MVA Sum	Concurrent MVA	Concurrent MWe Eff Losses (CTF Bldg)	MWe Eff Losses (H2PS Bldg)	MWe Eff Losses (Water Bldg)
Tower			Tower Fans	43.71		0.51		480	C	1		685	80%	0.64	100%	0.64					
Tower			Tower Circ Pump		24,854	0.49		480	C	1		660	80%	0.62	100%	0.62					
WPB			Deep Well Pump		957	0.30		4160	C	1		407	80%	0.38	100%	0.38					Outside
WPB			Deep Well Pump Capacity - Spare		878	0.28		4160	C	1		373	80%	0.35	100%	0.35					Outside
IW			Industrial Waste Pump (10%)		354	0.00		480	C	1		4	80%	0.00	100%	0.00					Outside
WPB			Water Pressurization Pumps		3,539	0.26		480	C	1		347	80%	0.32	100%	0.32					Outside
			Subtotal:	∑ Deep Well	2,661	136.11					56.50			146.82		151.40		86.90	18.49	7.54	9.99
			Ave Future Growth	26.1%	878	35.49					14.73			38.28		39.48		22.66	4.82	1.97	2.61
					3,539	171.60					71.23			185.10		190.88		**109.56**			

NOTE: Under Source - C = Critical NC = Non-Critical U = UPS
Under Concurrent 1 = Included in load calc while 0 = Not Included

CTF – Summary

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Summary - All Loads	MW(t)	gpm	MWe	HP	Expected MVA	Design MVA
Heater:	76.11		77.67		78.63	78.63
Electrolysis Unit:		6	5.10		5.20	5.20
Circulator Motor:	15.36		17.02	22817	18.91	22.73
Circulator AMB:			1.89		2.10	2.10
Compressor:			1.37	1840	1.72	1.72
Water Purification & Treatment:		34	0.02		0.03	0.03
Chiller:	119.10		19.85	26609	24.81	24.81
Chiller Pump:		85037	1.01	1356	1.26	1.26
Tower Fans:	124.61		1.46	1954	1.82	1.82
Tower Circ Pump:		70864	1.40	1883	1.76	1.76
Deep Well Pump②:		3644	1.16	1549	1.44	1.44
Water Pressurization Pumps:		3539	0.26	347	0.32	0.32
Industrial Waste Pump:		354	0.00	4	0.00	0.00
Other:		0	7.90		8.80	9.57
② Does NOT Include Fire Water			136.11		146.82	151.40
Future Growth			35.49	Overall PF:	38.28	39.48
			171.60	92.7%	185.10	190.88

Summary - Concurrent Loads	MW(t)	gpm	MWe		HP	Expected MVA	Design MVA
Heater:	31.11		31.75			31.77	31.77
Electrolysis Unit:			5.10			5.20	5.20
Circulator Motor:	2.16		2.40	2.7	3211	2.66	2.66
Circulator AMB:			0.27			0.30	0.30
Compressor:			1.37		1840	1.72	1.72
Water Purification & Treatment:		19	0.01	9.52		0.01	0.01
Chiller:	54.15		9.03		12099	11.28	11.28
Chiller Pump:		40714	0.48		649	0.61	0.61
Tower Fans:	59.66		0.70	1.37	935	0.87	0.87
Tower Circ Pump:		33928	0.67		902	0.84	0.84
Deep Well Pump②:		2205	0.70		938	0.87	0.87
Water Pressurization Pumps:		2205	0.26		347	0.32	0.32
Industrial Waste Water:		221	0.02		32	0.03	0.03
Other:		0	5.07			5.66	5.66
② Does NOT Include Fire Water			57.81			62.14	62.14
Future Growth			15.07		Overall PF:	16.20	16.20
			72.89		93.0%	78.35	78.35

Concurrent By Building	MW(t)	gpm	MWe		Expected MVA	Design MVA
Component Test Facility:	39.35	0	35.43	46.1	35.98	35.98
CTF - Spare:			10.63		10.79	10.79
Hydrogen Processing Building:	0.999	6	8.65	9.5	9.23	9.23
H2PS - Spare:			0.87		0.92	0.92
Water Processing Building:	64.14	46476	11.11	14.0	13.82	13.82
WPB - Spare:			2.90		3.60	3.60
Tower Fans & Pumps:		62616	1.37	1.7	1.71	1.71
Tower - Spare:			0.36		0.45	0.45
Warehouse:			0.78	1.0	0.87	0.87
Warehouse - Spare:			0.20		0.23	0.23
Other:			0.45	0.6	0.50	0.50
Other - Spare:			0.12		0.13	0.13
Industrial Waste Water:		221	0.02	0.0	0.03	0.03
IW - Spare:			0.01		0.01	0.01
			72.89		78.27	78.27

Overall PF:
93.1%

NOTE: * Difference is the smaller IW Loads
& Water Pressurization Pumps

Diesel Generator Summary by Building (DSFerguson 04/01/2008 07:59AM)

Bldg/Area		MW	Sum	Expected MVA	Design MVA	Sum	Ave Duration Hr	Fuel Est gal
CTF:		2.52	3.27	2.81	2.81	3.66	48.00	7333
CTF Spare:		0.76		0.84	0.84		48.00	2200
H2PS:		1.44	1.59	1.79	1.79	1.97	48.00	4207
H2PS Spare:		0.14		0.18	0.18		48.00	421
Water Process Building:		10.64	13.41	13.29	13.29	16.76	48.00	30987
WPB Spare:		2.77		3.47	3.47		48.00	8079
Tower Fans & Pumps:		1.37	1.73	1.71	1.71	2.16	48.00	3993
Tower Spare:		0.36		0.45	0.45		48.00	1041
Industrial Waste Water:		0.00	0.00	0.00	0.00	0.00	48.00	8
IW Spare:		0.00		0.00	0.00		48.00	2
Other:		0.00		0.00	0.00		—	0
Warehouse:		0.00		0.00	0.00		—	0
UPS (from below):		0.60	0.76	0.67	0.67	0.84	48.00	1752
		0.16		0.17	0.17		48	457
		20.76		25.39	25.39			60480
Assume Cat 9CM32 Units	4.19	7		Units	Calc PF	Safety Factor		2
48 hr		0.82		Tank gal:	120960			

UPS Summary by Building

Bldg/Area		MW	Sum	Expected MVA	Design MVA	Sum
CTF:		0.50	0.65	0.55	0.55	0.72
CTF Spare:		0.15		0.17	0.17	
H2PS:		0.08	0.10	0.09	0.09	0.10
H2PS Spare:		0.02		0.01	0.01	
Water Process Building:		0.03	0.03	0.03	0.03	0.04
WPB Spare:		0.01		0.01	0.01	
Tower Fans & Pumps:		0.00	0.00	0.00	0.00	0.00
Tower Spare:		0.00		0.00	0.00	
Industrial Waste Water:		0.00	0.00	0.00	0.00	0.00
IW Spare:		0.00		0.00	0.00	
Other:		0.00		0.00	0.00	
Warehouse:		0.00		0.00	0.00	
		0.79		0.85	0.85	
		Calc PF:	0.92			

Appendix C

Codes & Standards

Appendix C

General

The following codes and standards have been identified as applicable or potentially applicable, in whole or part, during the design phase. The list is not intended to be all inclusive and as such does not contain all the codes and standards that may ultimately apply to the design. Nor are the codes and standards called out that will also apply during the operation, maintenance, and decommissioning of the facility.

International Code Council

International Code Counsel

IBC	International Building Code 2006 Edition
IFGC	International Fuel Gas Code
IMC	International Mechanical Code
UPC	Uniform Plumbing Code 1997 Edition

Civil Codes & Standards

Civil Codes

xxx	XXXXXXXXXXX

Structural Codes & Standards

Structural Codes

xxxx	XXXXXXXXXXX

Mechanical Codes & Standards

Potable Water

IDAPA	XXXXXXXXXXX

Sanitary Sewer

IDAPA	XXXXXXXXXXX

HVAC and Ducting

ASHRAE	XXXXXXXXXXX
SMANCA	XXXXXXXXXXX

Compressed Gases

CGA	XXXXXXXXXXX

Fuel Gases

National Fire Protection Association (NFPA) XXXXXXXXXXX

Fire Protection Codes & Standards

NFPA

NFPA 1	Fire Prevention Code 2006 Edition
NFPA 10	Standard for Portable Fire Extinguishers 2007 Edition
NFPA 13	Standard for the Installation of Sprinkler Systems 2007 Edition
NFPA 14	Standard for the Installation of Standpipe, Private Hydrant, and Hose Systems 2007 Edition
NFPA 15	Standard for Water Spray Fixed Systems for Fire Protection 2007 Edition
NFPA 16	Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems 2007 Edition
NFPA 17	Standard for Dry Chemical Extinguishing Systems 2002 Edition
NFPA 18A	Standard on Water Additives for Fire Control and Vapor Mitigation 2007 Edition
NFPA 20	Standard for the Installation of Stationary Pumps for Fire Protection 1999 Edition
NFPA 22	Standard for Water Tanks for Private Fire Protection 2008 Edition
NFPA 24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances 2007 Edition
NFPA 30	Flammable and Combustible Liquids Code 2008 Edition
NFPA 37	Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines 2006 Edition
NFPA 45	Standard on Fire Protection for Laboratories Using Chemicals 2004 Edition
NFPA 50	Standard for Bulk Oxygen Systems at Consumer Sites 2001 Edition
NFPA 51	Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes 2007 Edition

NFPA 53	Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres 2004 Edition
NFPA 54	National Fuel Gas Code 2006 Edition
NFPA 55	Standard for the Storage, Use, and Handling of Compressed Gasses and Cryogenic Fluids in Portable and Stationary Containers, and Tanks 2005 Edition
NFPA 57	Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code 2002 Edition
NFPA 59A	Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG) 2006 Edition
NFPA 68	Guide for Venting of Deflagrations 2007 Edition
NFPA 69	Standard on Explosion Prevention Systems 2008 Edition
NFPA 70	National Electrical Code 2008 Edition
NFPA 70E	Standard for Electrical Safety Requirements for Employee Workplaces 2004 Edition
NFPA 72	National Fire Alarm Code 2007 Edition
NFPA 75	Standard for the Protection of Electronic Computer/Data Processing Equipment 2003 Edition
NFPA 77	Recommended Practice on Static Electricity 2007 Edition
NFPA 79	Electrical Standard for Industrial Machinery 2007 Edition
NFPA 80	Standard for Fire Doors and Fire Windows 2007 Edition
NFPA 80A	Recommended Practice for Protection of Buildings from Exterior Fire Exposures 2007 Edition
NFPA 85	Boiler and Combustion Systems Hazards Code 2007 Edition
NFPA 86	Standard for Ovens and Furnaces 2007 Edition
NFPA 90A	Standard for the Installation of Air-Conditioning and Ventilating Systems 2002 Edition
NFPA 90B	Standard for the Installation of Warm Air Heating and Air-Conditioning Systems 2006 Edition
NFPA 91	Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids 2004 Edition
NFPA 96	Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations 2008 Edition
NFPA 99C	Standard on Gas and Vacuum Systems 2005 Edition
NFPA 101	Life Safety Code 2006 Editions
NFPA 105	Standard for the Installation of Smoke Door Assemblies 2007 Edition
NFPA 110	Standard for Emergency and Standby Power Systems 2005 Edition

NFPA 111	Standard on Stored Electrical Energy Emergency and Standby Power Systems 2005 Edition
NFPA 170	Standard for Fire Safety Symbols 2006 Edition
NFPA 214	Standard on Water-Cooling Towers 2005 Edition
NFPA 220	Standard on Types of Building Construction 2006 Edition
NFPA 221	Standard for Fire Walls and Fire Barrier Walls 2006 Edition
NFPA 230	Standard for the Fire Protection of Storage 2003 Edition
NFPA 232	Standard for the Protection of Records 2007 Edition
NFPA 262	Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces 2007 Edition
NFPA 430	Code for the Storage of Liquid and Solid Oxidizers 2004 Edition
NFPA 496	Standard for Purged and Pressurized Enclosures for Electrical Equipment 2008 Edition
NFPA 497	Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas 2008 Edition
NFPA 499	Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas 2008 Edition
NFPA 750	Standard on Water Mist Fire Protection Systems 2006 Edition
NFPA 780	Standard for the Installation of Lightning Protection Systems 2008 Edition
NFPA 801	Standard for Fire Protection For Facilities Handling Radioactive Materials 2008 Edition
NFPA 820	Standard for Fire Protection in Wastewater Treatment and Collection Facilities 2008 Edition
NFPA 2001	Standard on Clean Agent Fire Extinguishing Systems 2008 Edition
NFPA 2010	Standard for Fixed Aerosol Fire-Extinguishing Systems 2006 Edition

Electrical Codes & Standards

General Facility Electrical Codes and Standards

NFPA 70, “National Electric Code (NEC).

NFPA 70E, Electrical Safety Requirements for Employee Workplaces.

IEEE-C2, National Electrical Safety Code.

DOE-HDBK-1092, DOE HDBK, Electrical Safety.

IEEE-803, IEEE Recommended Practice for Unique Identification in Power Plants and Related Facilities.

Normal Power System Codes and Standards

IEEE-STD 141, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, Red Book.

NFPA 79, Electrical Standard for Industrial Machinery.

IEEE-STD 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power, Buff Book.

IEEE-STD 493, IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems, Gold Book.

UL-508, Industrial Control Equipment.

International electrical Testing Association-ATS, International Electrical Testing Association, Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

Standby Power System Codes and Standards

IEEE-STD 446, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications, Orange Book.

IEEE-STD 519, IEEE Recommended Practice and Requirements for the Harmonic Control in Electrical Power Systems.

IEEE-STD 141, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, Red Book.

IEEE-STD 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power, Buff Book.

NFPA 110, Emergency and Standby Power Systems.

NFPA 111, Stored Electrical Energy Emergency and Standby Power Systems.

Uninterruptible Power Supply System Codes and Standards

DOE-SPEC-3021, Uninterruptible Power Supply (UPS) systems.

IEEE-944, IEEE recommended practice for the application and testing of Uninterruptible Power Supplies for Power Generating Stations.

Lighting System Codes and Standards

NFPA 101, Sections 5.8, 5.9, and 5.10; Life Safety Code.

IES, Lighting Handbook.

Grounding System Codes and Standards

IEEE-80, IEEE Guide for Safety in AC Substation Grounding

IEEE-STD 142, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems, Green Book.

IEEE-1050, IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations.

IEEE-1100, Chapter 9, Recommended Practice for Powering and Grounding Sensitive Electronic Equipment Emerald Book.

NFPA 77, Recommended Practice on Static Electricity.

Lightning Protection System Codes and Standards

NFPA 780, Lightning Protection Code.

UL-96A, Installation Requirements for Lightning Protection Systems.

Telephone System Codes and Standards

ANSI/TIA/EIA 568 B.1, Commercial Building Telecommunications Cabling Standard Part 1: General Requirements.

ANSI/TIA/EIA 568 B.2, Commercial Building Telecommunications Cabling Standard Part 2: Balanced Twisted Pair Cabling Components.

ANSI/TIA/EIA 568 B.3, Optical Fiber Cabling Components Standard.

TIA/EIA 569 A, Commercial Building Standards for Telecommunications Pathways and Spaces.

TIA/EIA 607, Commercial Building Grounding and Bonding Requirements for Telecommunications.

I&C and Building Management System Codes and Standards

DOE STD 1039, Guide to Good Practices for Control of Equipment and System Status.

ISA S5.1, Instrumentation Symbols and Identification .

ISA S5.3, Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems.

ISA S5.4, Instrument Loop Diagrams.

ISA S5.5, Graphic Symbols for Process Displays.

IEEE-1050, IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations.

IEEE-1046 Application Guide for Distributed Digital Control and Monitoring for Power Plants.

UL-1998, UL Standard for Safety for Software in Programmable Components.

IEC 61508, Functional Safety - Safety Related Systems.

ANSI B11-19 Sections 5.2 and 5.5, American National Standard for Machine Tools - Safeguarding when referenced by the other B11 Machine Tool Safety Standards - Performance Criteria for design, construction, care, and operation.

IEEE-C37.96-2000, IEEE Guide for AC Motor Protection.

UL-1998-1998, UL Standard for Safety for Software in Programmable Components.

NEMA ICS Standards.

NEMA MG-2, Safety Standard for Construction and Guide for Selection, Installation, and Use of Electric Motors.

IEEE-1046, Application Guide for Safety for Software in Programmable Components

IEEE-1100, Recommended Practice for Powering and Grounding Sensitive Electron Equipment - Emerald Book.