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Project Title:
Small-Scale Flexible Advanced Ultra-Supercritical Coal-Fired Power Plant with Integrated Carbon Capture

Pre-FEED Contract:
Coal-Based Power Plants of the Future – Technology Gap Analysis Report

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1 Technology

1.1 Current State of the Art

Current state-of-the-art coal-fired pulverized coal (PC) power plants operate at ultra-supercritical (USC) steam conditions, which have traditionally been defined by EPRI as temperatures more than 1200°F (649°C). Due to material mechanical property limitations, the maximum steam temperature typically used with the currently available ferritic steels is 1130°F (610°C) for the main steam and 1150°F (621°C) for the reheat steam. AUSC steam conditions are at temperatures above those of USC plants. USC steam power plants can be constructed of materials with a documented track record in commercial operations. Going to higher steam temperatures (and pressures) can achieve higher steam plant efficiencies, improving the performance of the plant and reducing emissions, including CO_2. Materials of construction are the limiting factor to achieve higher temperatures. The ferritic materials that are suitable for the high-temperature portions of USC power plants will not be adequate for steam temperatures higher than the current state-of-the-art.[1]

While the current fleet of USC plants represents a significant advance, compared to earlier subcritical and supercritical plant designs, the state-of-the-art USC plants, they still have some key shortcomings, limitations, and challenges. The overall plant efficiency of USC plants is limited by the conventional (ferritic) materials of construction, which support steam temperatures up to 1150ºF (621ºC). Emissions of current state-of-the art USC plants are still greater than those of natural gas technologies. Most current USC plants have been designed to be base loaded, and have limited capability to achieve high ramp rates, and low minimum loads. Typical USC plants also have relatively high water consumption. These plants also have long construction schedules, and rely on extensive field-erection and assembly.

1.2 How Proposed Plant Concept Will Overcome Shortcomings

The primary benefit of employing AUSC steam conditions is a significant increase in net plant efficiency associated with the higher steam temperatures and the attendant reduction in fuel use and associated CO_2 production (per unit net MWh output). In addition to increased efficiency, the proposed concept addresses shortcomings of other coal-fired plants, including the following:

- <u>Size</u>: Large (800+ MWe) scale base-load coal fired power plants are not an ideal fit for the modern electrical grid. The small (300 MWe gross) size of the proposed concept would integrate better in a scenario that includes electricity generated from intermittent renewable sources.
- <u>Flexible Operation</u>: The majority of existing coal fired power plants were originally designed for optimal operation under base load conditions, which limits the options for cycling and low load operation for these types of plants. Coal-fired power plants are increasingly called upon to operate in load-following and cycling operation to support intermittent renewable capacity, and to provide critical ancillary services to the grid. The power plant concept

[1] *Novel Cycles Database Report: 2018*. EPRI, Palo Alto, CA: 2018. 3002014390.

provides enhanced cycling flexibility for an optimized operation regime for transient operation (i.e., fast start-up, load changes, dynamic cycling, etc.) to allow for flexible response to grid requirements, savings at start-up of initial power and thermal power consumption, and a more agile power plant that can provide more opportunities to bid in power markets. The conceptual design includes use of nickel-based alloys for selected thick walled components to minimize thermal stress during load cycling, an innovative furnace arrangement to ensure uniform heat absorption, uniform outlet temperature distribution, and uniform thermal expansion that will allow fast startups and rapid load swings, and digital solutions for achievement of the target ramping rates. The GE NID™ dry FGD system will help to support flexible operation of the conceptual design. The FGD system will include multiple operating modules at the maximum full-load capacity, and in turn-down the controls can allow just one module to be in service.

- Emissions: The goal of new coal fired power plants is to achieve near-zero emissions, with low amounts of carbon dioxide (amounts that are equal to or lower than natural gas technologies). The concept includes selective catalytic reduction for NO_x control and a NID™ dry scrubber/fabric filter for particulate matter, SO_2, mercury and acid gas control. The concept also includes integrated post-combustion capture for CO_2 control.
- Water Use: Water consumption in the proposed concept is addressed by use of GE's NID™ technology for flue gas desulfurization.
- Modular: The proposed concept incorporates shop modularization of selected boiler convective pass, AQCS, and steam turbine components.
- Cost: While the increased efficiency of the AUSC concept comes with a capital cost premium, compared to a traditional USC plant, the proposed concept includes several features that are aimed at reducing AUSC plant costs. The proposed concept does not push steam temperatures to the upper range of AUSC conditions. By limiting the superheat steam temperatures in the proposed concept to 650°C, and reheat steam temperatures to 670°C, the amount of higher-cost, nickel-based alloy materials required is limited, thus helping to control capital costs. While limiting the steam temperature, to below the maximum allowed by the nickel-based alloy materials, will necessarily have an impact upon the thermal efficiency, it also provides an economic advantage, due to the lower cost of materials. Further, the ability to use nickel-based alloys, such as Inconel 740H (IN740H), below their maximum operating range allows the designer to take advantage of their mechanical properties to support faster operational transitions, while minimizing fatigue damage and extending component life. Based upon market experience, GE sees the present cycle conditions for this concept as a sweet spot for small scale AUSC technology deployment in the future. Additionally, the boiler convective pass has been designed to using a close-coupled arrangement, in which the horizontal high temperature convective surfaces have SH and RH header outlets at the front wall instead of the top of the boiler, yielding 25-30% shorter high energy piping runs than a typical arrangement. Elimination of the tunnel between the furnace exit vertical plane and low temperature convective pass results in a more compact boiler footprint, results in lower cost, compared to a traditional 2-pass pulverized coal boiler design. The operating and maintenance costs are expected

to be slightly higher, compared to other pulverized coal plants of similar size, and will be calculated in the Pre-FEED phase of this project.

- Schedule: The proposed AUSC concept will reduce design, construction, and commissioning schedules, compared to traditional USC plants, through the use of modular shop fabrications concepts for selected boiler convective pass assemblies, the NID™ FGD system, and steam turbine modules.

1.3 Key Technical Risks of Proposed Concept

There are several key technical risks associated with the proposed concept, as follows:

- Materials of Construction: Based on the conceptual design, the most likely candidate materials suitable for long service at steam temperatures approaching 650°C main steam temperature would include Sanicro 25, HR6W, P93, MarBN, and IN740H. The IN740H is critical for the highest metal temperature application including tubing, headers, and piping. Many of these alloys are nonstandard materials in current boiler applications, and only some have full American Society of Mechanical Engineers (ASME) code approval. There is limited in-service experience for some of these materials, especially at the AUSC conditions, and there is a risk that the long-term behavior of these alloys may differ from the expectations.
- Supply Chain for Advanced Materials: The construction of the AUSC concept plant would require the supply chain to deliver several large components, made of nickel-based alloys. Such components have never been fabricated, at the required scale, using the alloys needed to support AUSC steam conditions. There are risks associated with first-of-a-kind fabrication of pipe extrusions, castings, and forgings, as well as the associated machining, welding, inspection and repair operations.
- Design Codes for Advanced Materials: The pressure parts of proposed concept AUSC power plant would generally need to be designed to ASME Boiler and Pressure Vessel Code. Since the nickel-based alloy materials are relatively new, some of the required materials, components, fabrication processes, and inspection criteria have not yet been incorporated within the ASME Code. There is a risk that OEMs may not be able to design, and customers will not be able to accept, AUSC power plants, if the ASME Code does not include sufficient coverage for the new advanced nickel-based alloys.
- AUSC Boiler Design: The innovative AUSC boiler design presents challenges. The fluid cooled boiler enclosure will incorporate an advanced over-fired air (OFA) system and must account for its effects on heat absorption in the furnace. The boiler design will use a spiral/vertical water wall arrangement in a more compact design to ensure uniform heat absorption, uniform outlet temperature distribution, and uniform thermal expansion to allow fast startups and rapid load swings. Similarly, work is needed on header, terminal tube and interconnecting link design and arrangement. Increasing the number of links between heat exchanger sections reduces the OD and thickness of the links and headers making them more flexible during rapid changes in firing rate. The ultrahigh

temperature finishing steam sections are arranged in a more compact configuration.

- AUSC Steam Turbine Design: While the proposed concept is based on a foundation of established technologies within GE, the application of these technologies in the proposed configuration, for the AUSC steam parameters and at the anticipated scale, represents an innovative step forward in steam turbine design. There is technical risk associated with the use of a first-of-a-kind AUSC steam turbine. Within the turbine train there is uncertainty about the location of steam extractions (especially for carbon capture requirements), optimized cycle for final steam paths, rotor dynamics, thermal expansion and location of axial bearings. The HP and IP valves would need to be redesigned at a smaller size, with advanced materials. The HP and IP turbines would need a revised blade path layout for the AUSC steam conditions. There is also a need for advanced sealing, to improve efficiency and lower steam excitation forces. Long Lead Items (rotor and castings) can be released for purchase in 2022-23 based on the AUSC ComTest component fabrication demonstration results. For the steam turbine costs provided herein, this time frame is feasible. Internally, testing for MarBN as a cost out option is ongoing. Readiness for 2022-23 may not be guaranteed, due to uncertainty of the outcome of the ongoing activities.

- Carbon Capture System: The Advanced Amine Process (AAP) was selected for this Plant Concept. While this technology is not transformative, it has already been extensively validated at the pilot scale (1 MW) on a slip-stream flue gas from a hard coal-fired power plant. At the demonstration facility, the pilot plant was operated efficiently and safely both at steady-state and under transient conditions. AAP comprises a proprietary amine-based solvent in a proprietary flow scheme for flue gas applications. The AAP technology applied to this Plant Concept is based on a reference design for large scale post-combustion capture plants, but downscaled to process the flue gas from target host plant capacity (equivalent of 300 MWe). Therefore, no technology gap associated with the validated design scaled down to 300 MWe is expected. Potential technology gaps may result from multi-year plant operation at the 300 MWe- scale but are not identified nor anticipated at this time.

1.4 Assessed Technology Gaps and R&D Needed for Commercialization by 2030

The proposed concept is expected to be at an appropriate level of readiness to enable a high-quality pilot plant (or potentially full-scale demonstration plant) FEED study in the 2022 timeframe. The remaining technology gaps would be addressed via a combination of:

1. Work being performed under this Coal FIRST Pre-FEED effort (DOE Contract 89243319CFE000023),
2. The A-USC ComTest Phase II effort (DOE DE-FE0025064),
3. Separate boiler design R&D effort, as outlined in Section 2.2,
4. Separate steam turbine design R&D effort, as outlined in Section 2.2, and

Consequently, assuming successful execution of these efforts, the schedules and work scopes of these identified projects are compatible with the initiation of a coal-based pilot plant FEED study in the 2022 timeframe. This timeframe also supports the commercialization of the proposed concept by 2030.

1.5 Development Pathway Description

Due to a decade and a half of DOE-sponsored R&D, with technical leadership and management provided by EPRI, materials are now available for use in coal-fired steam cycles that will support designs with steam temperatures up to 760°C. Previous DOE-funded work, which included steam-loop testing in an operating coal-fired boiler setting, validated that there are nickel-based alloys available that are suitable for use in these AUSC steam conditions.[2]

This earlier work has been followed by a subsequent DOE-funded component testing (ComTest) project, aimed at constructing full-scale nickel-based alloy components designed for AUSC service, validating the US domestic supply chain for these components, and closing the technical gaps to support the readiness to construct a commercial scale (300 MWe) AUSC pilot demonstration plant. Specific AUSC component areas that are being addressed in the current DOE-funded ComTest Phase II project include:

1. Pressure Relief Valve (PRV) – Qualification testing of PRVs to qualify valve designs for AUSC conditions.
2. Boiler Pressure Parts – Fabrication and assembly of commercial-size superheater and reheater (SH/RH) pressure parts, including nickel-based alloys, with simulated field erection and field repair:
    a. Inlet and outlet headers
    b. SH/RH tubing
    c. Tube membrane panel with weld overlay
    d. Weldments incorporating advanced materials
3. Pipe – Extrusion, bending, and welding of large diameter, thick wall, nickel-based alloy pipe.
4. Wye Forging – Fabrication of forged "wye" fittings to transfer steam from the reheater line to the turbine inlet.
5. Steam Turbine – Fabrication and validation of key full-scale steam turbine components:
    a. Nozzle carrier casting: 9500 kg casting of nickel-based alloy
    b. Rotor forging: Manufacture 76 cm diameter triple-melt ingot made using a Vacuum Induction Melting-Electroslag Remelting-Vacuum Arc Remelting process, to be forged into a 305 cm long step rotor forging.

Additionally, as part of the ComTest Phase II project, the project team will address the need for ASME Code Cases, which would be needed to allow designers to use certain nickel-based alloy components in future power plant applications, including

[2] Purgert, R., et al. (2015a). Boiler Materials for Ultrasupercritical Coal Power Plants, Final Report, DEFG26- 01NT41175, Energy Industries of Ohio (Independence, OH, USA).

commercial scale pilot demonstration. There are four ASME Code Case actions covered within ComTest Phase II:

1. Provide for alternative overpressure protection, as an alternative to a spring-operated PRV.
2. Expand ASME B16.34 to allow bolted-flange design at high temperatures.
3. Revise ASME Code Case 2902 for IN740H, to permit the use of shielded metal arc welding as a permissible welding process.
4. Permit the use of wrought forms of Haynes 282 in A-USC power plants.

GE has identified a set of steam turbine components, and associated R&D development activities, as summarized in Section 2.2, which would serve to address the remaining technology gaps. The component areas identified include the following:

1. Turbine Train (optimization, rotor dynamics, thermal expansion, and axial bearings)
2. HP& IP Valves (small valve design, internals redesign)
3. HP & IP Turbines (blade path layout, redesign for small size with advanced materials)
4. Advanced Sealing (improved sealing efficiency and lower steam excitation forces)
5. Materials (Extension of MarBN to forged applications)

2 The Plant

2.1 Inventory of Commercial Equipment

The proposed small-scale flexible advanced ultra-supercritical coal-fired power plant with integrated carbon capture includes the following components:

- Boiler/AQCS island – Vendor: General Electric
    - Once-through AUSC pulverized coal-fired boiler in a close-coupled configuration with SH, RH, Economizer, Waterwalls and Separator
    - Start-up System
    - PA, FD and ID fans
    - Regenerative air preheater
    - SSC (submerged scraper conveyer)
    - Bowl Mills
    - Ultra-Low NOx Tangential Firing System
    - Scanning system
    - Selective Catalytic Reduction system (SCR)
    - Novel Integrated Desulfurization (NID™) dry FGD/fabric filter system
- Steam Turbine Island- Vendor: General Electric
    - HP turbine module
    - IP turbine module
    - LP turbine module
    - Main steam stop & control valve
    - Reheat stream stop & control valves
    - Bearing pedestals
    - Generator
- Balance of Plant by AECOM including:
    - Condenser and condensate pump
    - Deaerator
    - Boiler feed pump
    - Low pressure (LP) and high pressure (HP) feedwater heaters
    - Coal and Ash Handling Systems
    - DCS
    - Electrical Equipment including Transformers and Switchgear
    - MCC
    - Civil and Site Infrastructure
    - Waste Water, Cooling Water, Instrument and Service Air and Water
- Integrated Carbon Capture System Block – Vendor: Baker Hughes / General Electric:
    - Flue Gas Handling System
        - Flue Gas Cooler
        - Flue Gas Cooler Exchanger
        - Axial Booster Fan
    - CO_2 Absorption System
        - CO_2 Absorber
        - Absorber Water Wash Cooler
        - Lean Solution Cooler

- Regeneration System
  - Regenerator Column
  - Regenerator Water Wash Cooler
  - Rich/Lean Solution Exchangers
  - Regenerator Reboiler
- CO_2 Compression
  - CO_2 Compressor
  - CO_2 Dryer Skid
- Solvent Filtration and Reclamation System
  - Solvent Solution Filter System
  - Solvent Reclaimer Unit
- Tanks
  - Solvent Storage Tank
  - Auxiliary Storage Tank
  - Chemical Storage Tanks
  - Anti-Foam Tote
  - Solvent Drain Tank
  - Make-up Water Tank
- Various drums, pumps and heat exchangers

2.2 Equipment Requiring R&D

GE is a leader in the design of pulverized coal fired boilers ranging in capacity from 100,000 lbs/hr at 250 psig to over 7,000,000 lbs/hr and pressures exceeding 5000 psig. Final outlet steam temperatures of up to 1200 F have been attempted in the past. This experience has demonstrated the need for improved materials and the development of an improved boiler design that is robust and flexible.

The plant concept proposed is based on a foundation of established technologies within GE for both boilers and steam turbines. Nevertheless, the application of these technologies in the proposed configuration, for the foreseen steam parameters and at the anticipated scale, represents an innovative step forward for which the following boiler and steam turbine development work is required.

This innovative, small flexible AUSC boiler design presents many challenges. Development work will be needed on the fluid cooled boiler enclosure to incorporate the advanced OFA system and its effects on the heat absorption in the furnace. The boiler design will use a spiral/vertical water wall arrangement that will utilize a portion of the vertical waterwalls to form the side walls of the extended backpass to ensure uniform heat absorption, uniform outlet temperature distribution, and uniform thermal expansion that will allow fast startups and rapid load swings. Additional work would be needed to incorporate high-grade materials into the water wall fin welded membranes to address the pressures and temperatures of the AUSC boiler.

Similarly, work is needed on header, terminal tube and interconnecting link design and arrangement. For example, increasing the number of links between heat exchanger sections reduces the OD and thickness of the links and headers making them more flexible during rapid changes in firing rate. The ultra, high temperature finishing steam sections will need to be studied to determine the best means of support for flexibility and any possible “corrosion resistant” arrangements.

Steam Turbine Components Requiring R&D

Component	Development
Turbine Train	– Water steam cycle optimization, including requirement and location of extractions, also covering carbon capture requirements. – Overall performance determination for optimized cycle using finalized steam paths. – Rotor dynamics feasibility for optimized reaction technology blade paths – Thermal expansion determination at elevated temperatures; confirmation of axial bearing location
HP & IP valves	– New valve design at small size with advanced materials, based on standard USC designs. – Redesign of internals with advanced materials. – Lifetime verification.
HP & IP turbines	– Blade path layout for defined steam conditions – Module redesign for small size with advanced materials, including lifetime verification.
Advanced Sealing	– For better sealing efficiency and lower steam excitation forces
Materials	– Extension of MarBN to forged applications

GE is a leader in the development of both cleaner coal technologies and Air Quality Control Systems, and is at the forefront of the development of carbon capture technology advancements. GE has designed and constructed 13 CO_2 Capture and Storage Solutions (CCS) demonstration projects around the world. These technologies are ready for large-scale implementation.

2.3 Steam Turbine

The steam turbine concept is based on a reference advanced Ultra-Supercritical (USC) cycle with steam parameters of 650°C/670°C/330 bar, but downscaled to an output of 300 MWe gross generating capacity. This concept combines the existing capabilities of the GE USC modular steam turbine product platform with the use of high temperature materials, scaled to a plant size normally associated with much lower steam conditions.

The proven modular steam turbine platform combines many design features supporting the evolution to more advanced and efficient steam cycles. Some of the features are unique to GE steam turbines and represent the best design practices developed over decades. These can be summarized as follows:

– Separated high pressure and intermediate pressure turbine modules using multiple shell casing design, with inner and outer casings cascading high temperature differences over several shells.

– Disk-type welded turbine rotors to apply new materials to the hottest and most exposed rotor sections. The optimized composition of materials in each rotor supports high operational flexibility combined with competitive product lifetime.

– Robust, multiple stage reaction type blading is used to moderate the pressure/ temperature drop per stage. Best suited steel alloys are available to offset the stage specific stress levels.

– A consequent compact steam turbine and turbo-generator design in combination with the proven single bearing concept (single bearings between adjacent modules) minimizes the overall shaft length.

– GE's pre-engineered and efficient low pressure steam turbine platform also offers sideways or downward exhausting steam designs to support optimized arrangement concepts and turbine hall layouts. (see Figure 2.3-1 and Figure 2.3-2)

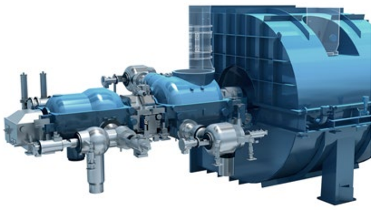

Figure 2.3-1 – Steam Turbine Train

(side exhaust option)

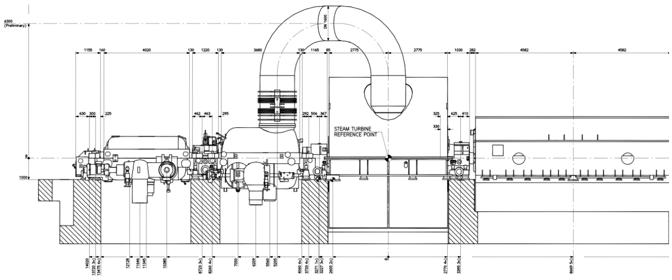

Figure 2.3-2 – Steam Turbine Train Including Generator
(downwards exhaust option)

2.4 Steam Generator and Auxiliaries

The design intent of the pulverized coal steam generator is to utilize only commercially available materials to avoid a Technology Gap. Although commercially available, it should be noted that further supply chain development will be needed to fabricate the advanced nickel-based alloys at the required scale.

The boiler concept is based on a reference advanced Ultra-Supercritical (USC) boiler with steam parameters of 650°C/670°C/330 bar, but downscaled to an output of 1,704,870lb/hr main steam flow with 300 MWe gross generating capacity. Material selections and temperature/pressure conditions are shown in **Figure 2.4-1**.

The boiler concept is an innovative close-coupled arrangement. The horizontal high temperature convective surfaces have SH and RH header outlets at the front wall instead of the top of the boiler, yielding 25-30% shorter high energy piping runs than a typical arrangement. Elimination of the tunnel between the furnace exit vertical plane and low temperature convective pass results in a more compact boiler footprint.

The furnace front, rear and side walls along with the first pass front wall, first and second pass division wall and side walls are all up flow fluid cooled. Only the roof and second pass rear wall and the first circuits after the separator are steam cooled. This innovative arrangement essentially addresses differential expansion between wall sections allowing faster start-up and higher load ramp rates.

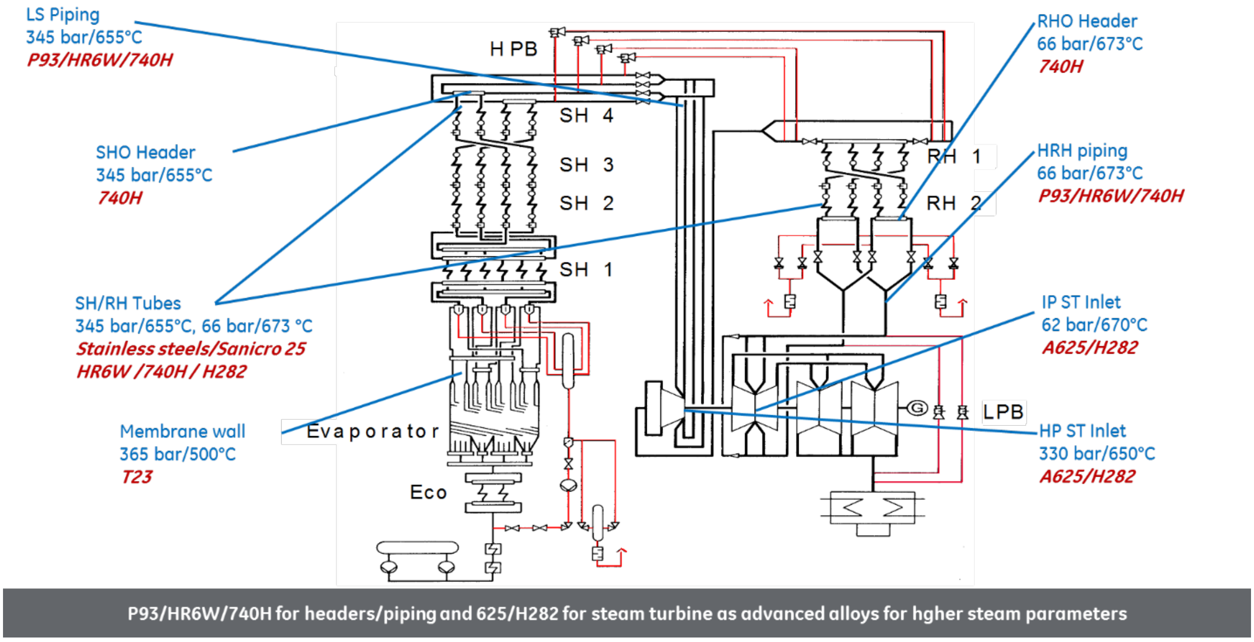

Figure 2.4-1 Boiler Pressure Part Components

All the Boiler auxiliary equipment such as the bowl mills, start-up system, PA, FD, ID fans and regenerative air pre-heater are commercially available mature technologies with no Technology Gaps.

2.5 AQCS systems

GE Power Inc.'s most recent development is the TFS XP™ Ultra Low NO_X Firing System. This system represents over 45 years of progressively developed global and local staging techniques designed to minimize O_2 availability during the critical early phases of combustion when the volatile (fuel) nitrogen species are formed. A key feature of this firing system is the tri-level OFA design consisting of "close coupled" overfire air (CCOFA) and two(2) levels of separated overfire air (SOFA). Moving the upper most SOFA windboxes from the traditional "corner" location to the furnace walls in a "counter" fireball orientation completed the design by providing superior mixing, minimum gas-side energy imbalance (GSEI) and control of CO emissions while operating at minimum NO_X emissions levels.

The TFS XP™ firing system has some additional important features including;

- Dynamic classifiers for improved mill performance (fineness and capacity)
- Concentric firing to maintain "oxidizing" conditions along the furnace walls in the firing zone, and
- Enhanced ignition coal nozzle tips for more rapid release of fuel nitrogen, improved coal combustion (lower UBC HL) and low load flame stability

The SCR system is a well proved post combustion technology for converting by-product NO_X to atmospheric N_2 at reduction efficiencies of +90%. The process involves injecting ammonia (anhydrous, aqueous or as urea) into the flue gas stream of an appropriate temperature and then passing the flue gas through a reactor vessel containing catalyst. An economizer gas bypass system will be used to control SCR inlet gas temperature. The reactor box is a standard multi-layer design with inlet turning vanes, flow straighteners, ash moving devices and integrated catalyst module removal system.

The particulate control and flue gas desulfurization (FGD) system design approach to be used will be GE's Novel Integrated Desulfurization (NID™) dry FGD/fabric filter system. This is a proven overall design that incorporates multiple modularized gas-solid entrained reaction sections followed by fabric filter modules. The NID™ system modular design fits well with the objectives of the Coal FIRST program, and the modular design allows for ease and speed of constructability. The entrained reactor section along with connected mechanical equipment can be pre-assembled in a workshop and transported to site. The fabric filter is built as modules on site and joined with the reactor section. The total NID™ module is lifted into place onto structural steel, then connected to flue gas inlet and outlet ductwork.

The NID™ system operates routinely with very low particulate and sulfuric acid emissions. Acid gas emissions can be controlled through the addition of lime reagent to reach high removal rates. Sulfur dioxide removal of greater than 98% is proven for long-term operation at a NID™ installation at a large Eastern US power plant. Additionally, SO_2 removal of 99% has been validated with pilot testing at GE's AQCS R&D center in Sweden. Additional design and controls concepts that require further full-scale implementation are anticipated to allow cost effective removal at greater than 99% on a continuous basis. Addition of hydrated lime to the ash recirculation duct allows use of higher sulfur content fuels. In addition to SO_2, the NID™ system has demonstrated long-term emission limits for HCl and Hg of <0.0001 lb/MMBtu and 0.4 lb/TBtu, respectively. This is a corresponding Hg removal rate of 96%. These very low emissions levels are important for consideration of downstream carbon capture technology where very low acid gas levels are generally preferred..

The NID™ dry FGD system helps minimize water consumption because it has no waste water stream. GE even has three installations using dry FGD technology to evaporate waste water from wet FGD systems and in one case cooling tower blowdown thus having advantage of eliminating or reducing another waste water stream from power plant. The extent to which water consumption is mimimized will be determined in the future Pre-FEED phase.

The NID™ modular design is also a key feature for the system turndown. For the Coal FIRST conceptual design, GE expects the system to include 4 operating NID™ modules at the full-capacity, and in turndown the controls can allow just two NID™ modules to be in service. Additional controlled turndown of each entrained gas-solid reaction chamber for each NID™ module is a relatively new feature in the GE design. Further development of the mechanical and control aspects of this module turndown feature that maintains the fluidized reactor functionality would be addressed in the Coal FIRST Pre-FEED effort. Gas-solid CFD and/or flow modeling of the individual module turndown response is an area that is recommended as part of this further design improvement.

3 Carbon Capture Plant

The carbon capture plant (CCP) is part of the planned air quality control system (AQCS) with the specific target to reduce the CO_2 emissions of the host power plant. The proposed CCP concept utilizes a proven Advanced Amine Process (AAP), comprising a proprietary amine-based solvent in a proprietary flow scheme for flue gas applications. The AAP technology applied is based on a reference design for large scale post-combustion capture plants, but downscaled to process the flue gas from target host plant capacity (equivalent of 300 MWe).

The main CCP plant performance target is 90% CO_2 capture from the pretreated flue gas of up-stream AQCS components, while producing a CO_2 product with specified quality in terms of composition and battery limit conditions – pressure and temperature – for further utilization.

These targets are accomplished with the objectives to achieve minimized utility consumptions, primarily steam and electrical power, but also cooling water and chemical consumptions, primarily amine make-up. Additional CCP plant integration options with the host power plant water/steam cycle could further improve the overall operations expenditures (OPEX) on cost of additional capital expenditures (CAPEX). Generally, amines-based processes are proven technologies for decades in the Oil & Gas industry. In this application, the process has been optimized to combustion flue gas under atmospheric pressure and power plant operations.

4 A&E Prior Work and Access to Information

EPRI has selected AECOM as the Architecture & Engineering (A&E) firm for the present Coal FIRST contract. AECOM is a leading, fully integrated, engineering firm that provides planning, consulting, architectural, engineering, procurement, construction, and design/build services to commercial and government clients worldwide. With approximately 87,000 employees, AECOM is number 164 on the 2018 Fortune 500 list with annual revenue of $20.2B+ (FY18). Their team of professionals has the experience and capabilities to successfully execute the full life cycle of a project. AECOM has experience in commercial pulverized coal fired power plants, and in executing Pre-FEED and FEED studies for AUSC plant designs.

EPRI, GE, and AECOM all have experience working together on projects to advance AUSC technology under multiple DOE-funded projects, including the ongoing AUSC ComTest (DE-FE0025064) and Evaluation of Steam Cycle Upgrades to Improve the Competitiveness of U.S. Coal Power Plants (DE-FE0031535) projects.

Under the ComTest Phase I project, AECOM was responsible for managing Pre-FEED, FEED, and detailed design activities of a pilot-scale AUSC unit balance-of-plant (BOP) design and equipment selection, as part of the ComTest Phase I project. Phase I included plans to design and construct an AUSC pilot plant at a host site located in Alabama. The AECOM work scope included design and selection of BOP equipment to support testing and operational demonstration of a 760°C AUSC steam turbine (GE design), steam superheater (GE design), and associated 760°C nickel alloy piping.

AECOM's engineering scope of work included overall process, BOP equipment, piping connections, host site infrastructure upgrades, utility tie-ins, and interface with significant collaboration of host site personnel and all subcontractors. Additional responsibilities included overall site management, project execution plan, risk assessment, process hazards analysis, environmental assessment, cost estimates, schedules, procurement, and construction. Under the present Phase II, AECOM has responsibility for maintaining the master schedule, and as part of this responsibility is interacting with GE, as well as nickel-based alloy suppliers, and component fabricators.

As part of the Evaluation of Steam Cycle Upgrades to Improve the Competitiveness of U.S. Coal Power Plants project, AECOM has responsibility to prepare project cost estimates and construction schedules for the upgrades to existing coal-fired power plants, including AUSC material technology options. This history of prior work makes AECOM ideally qualified to work with the OEM (GE) on this project, and demonstrates that AECOM has excellent access to the information on a broad spectrum of AUSC equipment.