Demonstration Boiler Facility

General Description

The EMS Energy Institute operates a 15,000 lb steam/h boiler system in which demonstrations of coal-based fuels fired in industrial boilers are conducted, hardware development and optimization is performed, emissions are characterized, and emissions control options are tested. The boiler is a D-type design watertube boiler manufactured by Tampella Power Corporation, rated for 15,000 lb/h saturated steam (@300 psig), and integrated into the University's steam distribution system. The boiler was designed to fire fuel oil but the overall system has been modified to fire coal-based fuels (i.e., coal-water slurry fuel (CWSF) and dry, micronized coal). The system has been modified to provide combustion air and CWSF preheating, fly ash and inorganic hazardous air pollutant removal from the flue gas using either a conventional fabric filter baghouse or a novel ceramic filter system, SO_2 removal using duct sorbent injection, coal unloading, storage, and crushing, and either CWSF preparation or dry coal micronization. The boiler windbox is configured to easily replace burners, specifically low-NO_x burners, for testing.

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Key Equipment

The facility can be operated firing either micronized coal or CWSF. Some components are common to both firing scenarios while other pieces of equipment are specific to either micronized coal or CWSF firing. The system is located in two buildings at University Park's East Campus Steam Plant except for the fabric filter baghouse, ceramic filter chamber, and duct sorbent injection system, which are located outdoors. The boiler and heat pipe heat exchanger are located in the boilerhouse, which is adjacent to Penn State's East Campus Steam Plant. Common coal processing and handling equipment is located in the Fuel Preparation Facility and includes a 25-ton coal hopper, a cage mill, several magnets, a Redler conveyor, a 3-ton surge bin, and a weigh-belt feeder. When firing micronized coal, a MicroEnergy Systems, Inc. (TCS) industrial mill is used to micronize the coal and a booster fan pneumatically transports the coal approximately 150 feet from the booster fan to the burner front in a four inch schedule 40 pipe contained in an underground trench. When firing CWSF, the fuel is produced using a hybrid CWSF double-stage grinding/mixing circuit located in the Fuel Preparation Facility. The CWSF preparation facility can be operated in three modes: 1) as a filter cake re-entrainment circuit; 2) as a single-stage grinding circuit; or 3) as a double-stage grinding circuit. After the CWSF is produced in the Fuel Preparation Facility, it is transferred to a 2,000-gallon surge tank located in the boilerhouse. From the storage tank, the CWSF passes through a burner pump, steam-heated preheater, and mass flow meter prior to being introduced into the burner/ atomizer.

The boiler's combustion chamber and convective pass have not been modified specifically for coal firing except that several ports were installed for flame observation, temperature and heat transfer measurements, erosion and deposition assessments, and ash/char sampling. The boiler windbox and front wall are configured to easily replace burners for testing.

Equipment Capabilities

Industrial Boiler/ Burner System

The industrial boiler system is used for hardware development, optimization, and evaluation, evaluating fuels and burners, and addressing environmental issues such as characterizing and controlling emissions. Examples of hardware that have been developed/ optimized/ evaluated include: burners, atomizers, control systems, a heat-pipe heat exchanger, fuel delivery systems, an industrial-scale pulverizer, combustion enhancers, and ash removal devices.

Several burners have been evaluated using the industrial boiler system, specifically low-NO_x burners. This includes both commercially available burners and those under development. Most of the burners tested have been multiple-fuel capable and include: Faber natural gas and oil-fired burner, ABB High Efficiency Advanced Coal Combustor (HEACC), ABB Radially-Stratified Flame Core (RSFC) burner, EER Low-NO_x burner, and Foster Wheeler Energy Corporation Low-NO_x burner.

Fuels that have been evaluated include: natural gas, No. 6 fuel oil, micronized bituminous coal and anthracite, Synfuels, coal-water slurry fuel, and filter cake from advanced coal cleaning processes.

Emissions Studies – Ceramic Filter Chamber, Conventional Fabric Filter Baghouse, & Duct Sorbent Injection System

The boiler system contains both a conventional fabric filter baghouse and a ceramic filter chamber. Both of the filtration systems were sized to filter the entire flue gas stream. The system was engineered so that the flue gas stream can be passed through either the baghouse or the ceramic filter chamber. The filtration systems are used to study fine particulate matter (PM_{10} and $PM_{2.5}$) and HAPs, both inorganic and organic, emissions when firing coal-based fuels in the industrial-scale boiler.

Penn State has the capabilities to perform stack sampling and routinely performs the following:

Method 1 – Sample and Velocity Traverse
Method 2 – Stack Gas Velocity and Volumetric Flow Rate
Method 3 – Dry Molecular Weight
Method 3A – Oxygen and Carbon Dioxide Concentration
Method 5 – Dust Loadings
Method 6C – Sulfur Dioxide Emissions
Method 7E – Nitrogen Oxide Emissions
Method 10 – Carbon Monoxide Emissions
Method 29 – Metals Emissions
Method 201A – Total PM and PM_{10} Emissions
Method 202 – Total Condensable Particulate Matter (CPM), inorganic CPM, and organic CPM

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Method 3510-C – Polycyclic Aromatic Hydrocarbon (PAH) Liquid Extraction
Method 3540-C – PAH PM Extraction
Method 4000 – Immunoassay Method for Dioxins/Furans
Method 8270-C – PAH Concentration
Ontario Hydro – Mercury Speciation
PSU Method – Mercury Speciation/ Total Metals

The demonstration boiler system is equipped with a duct injection system for SO_2 reduction. The sorbent is injected upstream of the particulate removal devices and is used to evaluate sorbents, both calcium and sodium based. The system is designed to handle 1-ton supersacks of sorbent.

Coal Storage, Handling, & Micronization Equipment

The industrial-scale preparation facility houses a dry coal micronization circuit to produce the fuel necessary to conduct testing in the demonstration boiler. The central coal feed system, with a nominal capacity of 1 ton/h, receives a 2” x 0” coal and is comprised of a 25-ton coal bin, cage mill, Redler conveyor, 5-ton surge bin, and a weigh-belt feeder. This central coal feed system delivers minus 0.25” coal to the industrial-scale pulverizer. In addition to providing coal for testing, the dry coal circuit is used to study power requirements pulverizing characteristics of coals.

Coal-Water Slurry Fuel Preparation

The Fuel Preparation Facility houses a CWSF circuit to produce the fuel necessary to conduct testing in the demonstration boiler and perform fuel formulation studies. The CWSFs are prepared in a hybrid CWSF double-stage grinding/mixing circuit and/or filter cake re-entrainment with a full array of quality assurance instrumentation.

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- ***Demonstration boiler schematic***
- ***Ceramic filter /fabric filter/ sorbent duct injection systems photo***
- ***Industrial-scale micronization mill***
- ***CWSF fuel preparation facility schematic***

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