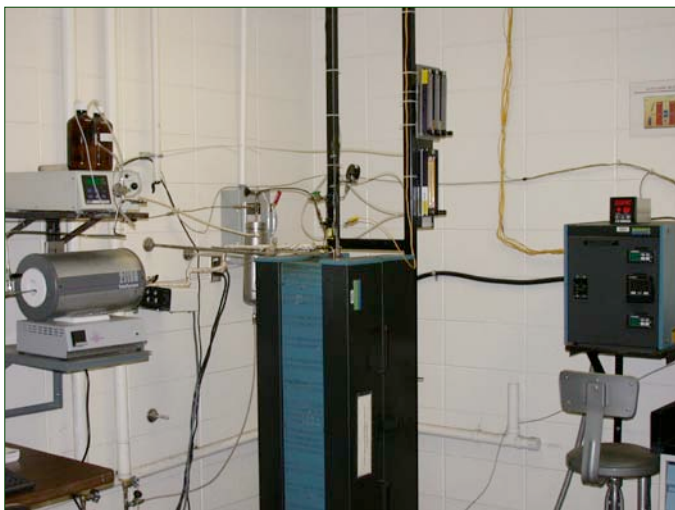


Activated Carbon Facility

General Description

The facility located at The Energy Institute is a lab-scale system that can be operated as an activation unit or as an on-line module for CO₂ capture and sequestration with integrated gasification. The facility has four main components: reactor/furnace, steam generator, temperature controller and on-line gas products analyzer (micro GC). The versatility of the design allows the use of different particle size, activating agent, heat treatment, residence time, flowrates and amount of sample. The control of the system as well as the data acquisition are conducted through a computer using commercial software.

The facility is currently used to produce activated carbons from different precursors, including coal-fired fly ash carbons and coals. The system is also used to activate carbonation minerals like serpentine and olivine to enhance their activities towards CO₂ sequestration. In addition, coals, biomass and municipal wastes are gasified to produce fuel gas or hydrogen with an integrated CO₂ sequestration module.



Activation Furnace

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College of Earth & Mineral Sciences • Penn State University

Key Equipment

The versatility of the facility allows us to operate this unit either to produce activated carbons or as an on-line module for CO₂ capture and sequestration with integrated gasification. The system consists of a fluidized bed reactor in a vertical furnace, a fixed bed in a horizontal furnace, a steam generator fed by an HPLC pump, and on-line gas detectors.

For the fluidized bed system, the fine particle reactant is locally suspended in the bed by blowing a gas stream upward through the bed to ensure a good contact between the solid and gas reactants. There are three different size fluidized bed reactors (diameter 20mm, 45mm and 73mm) that are operated depending on the experiment's objective and the characteristics of the feedstocks (i.e. particle size and density). The reactor is vertically placed in a furnace with three heating zones that can be operated up to 1100°C. The temperature of the furnace can be controlled manually by standard Eurotherm controller 818 or by using commercial NI LabVIEW software.

The fixed bed reactor is placed in the middle of a horizontal furnace to assure a uniform temperature zone. The furnace can be heated up to 1100°C. The reactor can be operated on-line with the fluidized bed described above.

A steam generator supplies the required steam for the activation and sequestration/gasification experiments. An HPLC pump delivers highly accurate water flowrates to a preheating coil.

The gas products can be analyzed on-line by an Agilent 3000 micro gas chromatograph. The solid products can be characterized by several analytical techniques, including 77K-N₂ and 273K-CO₂ isotherms to analyze their porosity, and determination of iodine numbers to evaluate their potential application.

During the operation procedure, the furnace is heated to the desired temperature, and a thermocouple inserted in the reactor monitors the sample temperature. The gases (steam, air, N₂ and CO₂) are preheated through a coil inside the furnace prior to entering the reactor. During the activation process, liquid products and water are collected in a condenser, while gases are analyzed on-line.

Equipment Capabilities



Agilent 3000 Micro-gas Chromatograph

Micro Gas Chromatograph

The Agilent 3000 micro-gas chromatograph, Agilent Technologies, Inc., is a two channel instrument that can be used to analyze on-line various gases, including CO₂, CO, N₂, and small chain hydrocarbons. The instrument uses self-contained GC modules, each consisting of an injector, columns, flow control valving, and a thermal conductivity detector (TCD), and can perform analyses in the order of seconds. Samples are introduced via a 1/6-inch Swagelok connection to the inlet(s) on the front panel. This design eliminates the need for traditional hypodermic syringe injection through septa. The inlet pressure can be less than 69kPa (10 psi) since an internal vacuum pump connected to the column exit eliminates column back pressure.

Porosity Analysis Instrument

The Autosorb-1 from Quantachrome Corporation operates by measuring the quantity of gas adsorbed onto or desorbed from a solid surface at some equilibrium vapor pressure by the static volumetric method. The data is obtained by admitting or removing a known quantity of adsorbate gas into or out of a sample cell containing the solid adsorbent maintained at a constant temperature below the critical temperature of the adsorbate. As adsorption or desorption occurs the pressure in the sample cell changes until equilibrium is established. The quantity of gas adsorbed or desorbed at the equilibrium pressure is the difference between the amount of gas

admitted or removed and the amount required to fill the space around the adsorbent (void space). The Autosorb-1 has the capability of measuring adsorbed or desorbed volumes of nitrogen at relative pressures in the range 0.001 to slightly under 1.0, and the relative pressures can be further lower to 0.00001 when the adsorbate gas is CO₂. The volume-pressure data can be reduced by the Autosorb-1 into BET surface area (single and/or multipoint), Langmuir surface area, adsorption and/or desorption isotherms, pore size and surface area distributions, micropore volume and surface area using t-plots, total pore volume and average pore diameter.



Quantachrome, Autosorb-1

Iodine Number Test

The test method follows ASTM D 4607-94, and covers the determination of the relative activation level of activated carbon by adsorption of iodine from aqueous solution. The amount of iodine adsorbed (in milligrams) by 1 g of carbon using test conditions is called the iodine number. This test method is based upon a three-point adsorption isotherm. A standard iodine solution is treated with three different known weights of carbon under specified conditions. The carbon treated solutions are then filtered to separate the carbon from the treated iodine solution (filtrate). The remaining iodine in the filtrate is measured by titration. The amount of iodine removed per gram of activated carbon is determined for each carbon dosage and the resulting data is used to plot an adsorption isotherm. The iodine number is reported as the amount of iodine adsorbed (in milligrams) per gram of carbon at a residual iodine concentration of 0.02N.

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