ELECTRICAL REGENERATION OF ACTIVATED CARBON USING THE ELECTROSOLV® PROCESS

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Introduction

ELECTROSOLV® is a process that has been developed by Foster-Miller to regenerate vapor phase granular activated carbon (GAC) *in situ* by taking advantage of the inherent electrical resistance of carbon [1]. The carbon is heated to its regeneration temperature by applying electrical power to electrodes placed at opposite ends of the carbon vessel. The carbon temperature increases as a result of the conversion of electrical energy to heat via joule heating. Temperature control is accomplished by modulating the power applied to the electrodes.

A 200 lb (91 kg) pilot scale system was tested at Hanscom AFB (Bedford, MA) to remove trichloroethylene (TCE) from the off-gases from an air stripping column. The dimensions of the carbon bed were 45.3 in. x 32.7 in. x 9.8 in. (high). The electrodes were placed normal to the flow direction. Although the pilot-scale system was effective in removing TCE, thermocouples placed throughout the carbon bed indicated large temperature gradients in the flow direction, as large as 170°C, between the top and bottom of the bed. An experimental investigation was undertaken to scale-up and reduce the temperature gradient throughout the carbon bed.

Experimental

A three foot diameter by ten foot high column containing 2180 lb (990 kg) of activated carbon (Barneby & Sutcliffe, Type 462, 4x8 mesh) was tested to determine the electrical and thermal characteristics of bulk carbon particles. The carbon bed was configured for a 3-phase electrical connection by dividing the column into three equivolume, pie-shaped sections using electrical insulating fiberglass cloth. Each section formed a resistive element that was connected electrically in a wye-configuration. The resistive elements were connected to a 460 V, 600 A, 3-phase delta feeder that was controlled by a manual switch. Opening and closing of the switch modulates the electric energy to the column.

The top of the column supported three electrodes; each electrode was a pie-shaped, 1/16 in. (1.6 mm) aluminum plate that was placed in contact with the carbon. Initially, the plates were backed up with one inch thick plywood and each loaded with 100 lb (45.4 kg) of bricks to maintain firm electrical contact between the electrode and the carbon and to make the stress uniform throughout the bulk carbon. During testing, the electrodes and method of top loading were modified.

The carbon column was instrumented for both electrical and temperature measurements. Each pie-shaped section was further subdivided by elevation into three equal volumes for a total of nine subsections. A thermocouple was placed near the centroid of each subsection to measure temperature. The voltage drop across each subsection was measured, as was the phase or line current to each section. All of the data were recorded by a Fluke Hydra digital data logger for subsequent presentation and analysis.

Results and Discussion

Testing of the column was initiated in August, 1996 and completed in March, 1997. After the initial tests were completed, the testing was stopped for a few months and resumed in January, 1997; 33 powered tests were completed during the test program. Heating of the column was limited to temperatures that for the most part did not exceed 100°C because of the low temperature limitations of the column material. Initially, the carbon was heated to a given temperature in a single pulse ranging from two to three minutes. In later runs, as the resistance of the column decreased, some temperatures increased to 100°C within 30 seconds. The power was pulsed on for 15 seconds and then off for 45 seconds through a series of seven pulses.

When testing was resumed in January 1997, the resistances in the column decreased from the previous measured values and the resistances in the top three subsections were higher than the lower six. Examination of the plywood sheets backing up the electrode showed scorching. To obtain better electrode to carbon contact, the plywood was eliminated and the weight of the bricks was increased by a factor of four. A voltage tap was placed two inches below the electrode. The column was repowered and voltage measurements showed that the voltage gradient or electric field dramatically increased as the electrode was approached (see Figure 2). The electrodes were modified to reduce the voltage gradient by inserting one inch long, No. 8 screws placed on a spacing pattern of one inch on center through the aluminum sheets. As shown in Figure 2, the voltage gradient was greatly reduced compared to the previous measurements. Thirteen more runs were made with this electrode configuration.

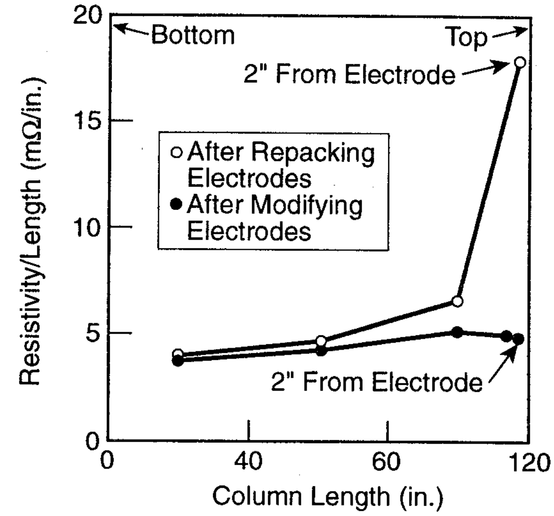

Figure 1. Distribution of the average resistance per unit length throughout the carbon column.

Figure 2 shows the temperature increase in each subsection of Section 1. The initial temperature of the carbon bed was approximately 40°C. The maximum temperature difference at any instant of time is not more than 10°C. These temperature distributions are representative of those in Sections 2 and 3 and for most of the powered runs.

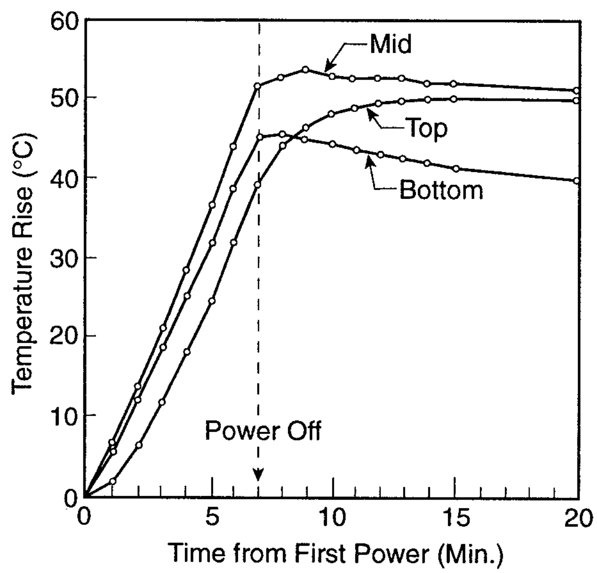

Figure 2. Temperature rise-time history of each subsection of Section 1.

The mid-height temperature rise in each section is a good indicator of the electrical power absorbed by the carbon. Each section has its own current and voltage drop and operates as a separate bed electrically. The power increases linearly between the initial and final heating pulse. For each subsection, the input power was taken to be the average of the initial and final values.

For a series of 12 tests, the standard variation from the mean value of the heat capacity (kJ/°C) in each midsection was at worst only 4.5 percent and ranged from 278 to 283 kJ/°C. The design carbon specific heat value was taken as 0.84 kJ/kg°C. For a subsection mass of 110 kg the heat capacity was calculated to be 277 kJ/°C, within 3.3 percent of the measured values.

Table 1 shows representative electrical values in each section. The average power in each section increased during the heating of the column as a result of the decrease in the resistance. The column resistances changed during and between tests. The average resistance of the nine subsections dropped during each test. These results could be explained by the negative thermal coefficient of resistance, which was calculated to range from -0.002 to -0.003 mΩ/°C. The variations in resistance are a result of thermal stresses on the carbon particles. As the carbon heats and tries to expand, the resistivity is lowered by induced thermal stresses.

Table 1. Electrical properties of carbon column.

Property[†]	Section 1		Section 2		Section 3	
	Init[‡]	Last[‡]	Init	Last	Init	Last
Current	453	509	472	527	471	525
Voltage	263	263	258	258	261	261
Power	119	134	122	136	123	137
Resistance						
Top	0.24	0.21	0.23	0.20	0.23	0.20
Middle	0.18	0.16	0.17	0.15	0.17	0.15
Bottom	0.16	0.15	0.14	0.14	0.16	0.14
Total	0.58	0.52	0.54	0.49	0.56	0.49

† Current, A; voltage, V; power, kW; and resistance, Ω.
‡ At initial application of power; after last application of power.

Conclusions

The three phase electrical wye-configuration resulted in relatively uniform heating of the carbon and produced energy balances within four percent of closure. Care must be taken to achieve a uniform resistivity, especially in the sections near the upper electrodes. This can be achieved by loading the electrodes and thermally cycling the carbon prior to use. Care must also be taken in designing the electrode to minimize the axial gradients in the electric field or voltage near the electrode.

Reference

1. Gold, H., Hicks, R.E., Harvey, A. and McCoy, III, J.F., U.S. Patent No. 5,565,077, October 15, 1996.