

[54] **PRODUCTION ACTIVATED CARBON IN
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[56]

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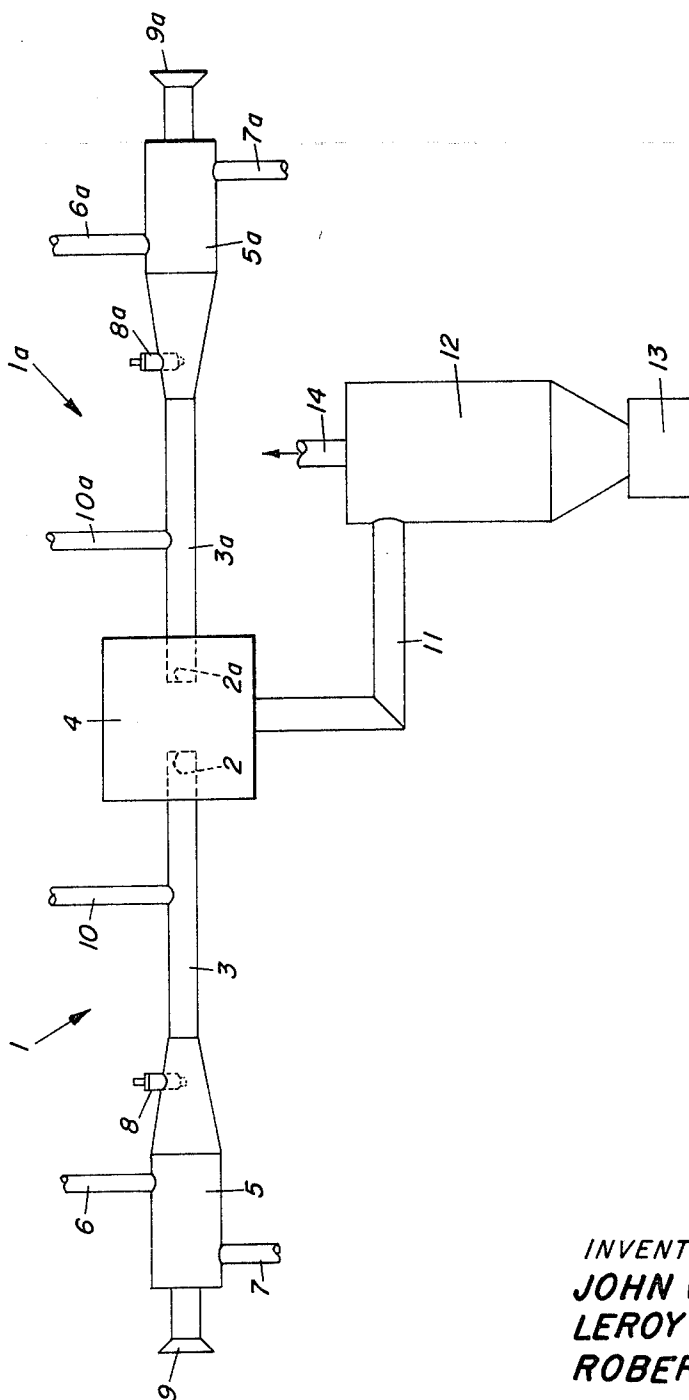
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ABSTRACT

A particulate carbonaceous feedstock such as lignite is entrained and activated in the oscillating combustion gas in the two opposed tail pipes of the dual pulse-jet engine system. Gas continually withdrawn from the juncture of the two pipes contains entrained activated carbon which is subsequently separated from the gas.

8 Claims, 1 Drawing Figure



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PRODUCTION ACTIVATED CARBON IN DUAL PULSE JET ENGINE SYSTEM

The invention relates to the production of activated carbon also known as active carbon or activated charcoal.

Activated carbon has attained widespread and important use as an adsorbent. Heretofore it has been produced from particulate carbonaceous feedstocks, such as lignite, anthracite, coconut shells, bone, etc., in a plurality of separate steps including drying, carbonization and activation. A typical procedure is described in "Activated Carbon" by John W. Hassler, Chemical Publishing Company, Inc., 212 Fifth Avenue, New York, N.Y. 1963.

We have now discovered that such activated carbon can be produced in a single step by the use of a dual pulse-jet combustion system. A detailed description of pulsating combustion is given in "Pulsating Combustion, the Collected Works of F. H. Reynst", edited by M. W. Thring, Pergamon Press, 1961. On pages 27 and 86 of this book a dual pulse-jet system is shown wherein two single pulse-jet tubes or engines of the same dimensions and configuration are located with the open end of their respective tail pipes immediately opposite one another so that the gases being expelled by one tail pipe pass into the other. Under this arrangement the jets will automatically work in opposed phase, i.e., one tube explodes while the other is drawing in air whereby the tubes reinforce the pulsations of each other. As used throughout the specification and claims, the phrase "dual pulse-jet" refers to such a system. In the present invention a particulate carbonaceous feedstock such as lignite is injected into the tail pipes as the hot gases of combustion are oscillating back and forth within and between the pipes. As a result, the feed particles are carried back and forth in an entrained state and "activated" by the high temperatures therein.

At the juncture of the two pulse tubes, the pressure remains substantially above atmospheric, and a gas which contains entrained activated carbon is continually drawn off therefrom and separated into a particulate product phase and a waste gas phase.

It is therefore an object of the present invention to employ the hot gases within the tail pipes of a dual pulse-jet combustion system to activate a particulate carbonaceous material.

Another object is to produce activated carbon in a single step.

Other objects and advantages will be obvious from the following more detailed description of the invention in conjunction with the drawing in which the figure shows a schematic view of the system of the present invention.

Referring to the drawing, reference numerals 1 and 1a represent two identically designed pulse jets. They are positioned so that the openings 2 and 2a, respectively, in their tail pipe sections 3 and 3a, respectively, are immediately opposite one another within a common plenum chamber 4. Propane or another liquid, solid, or gaseous fuel suitable for pulse-jets is injected into combustion chambers 5 and 5a through conduits 6 and 6a, respectively, together with compressed start-up air conveyed into the chambers by conduits 7 and 7a.

Ignition devices, 8 and 8a, such as a spark plug in each chamber, then ignite the air-fuel mixture, after which self-sustained pulsating combustion is carried on, in the prior art manner, in each pulse-jet. Throughout the operation, combustion air is drawn into the combustion chambers, during each suction cycle, through conduits 9 and 9a.

Tuning of the pulse-jets is automatic whereby one jet is exploding and expelling gases as the other is drawing in gases including combustion air. Thereafter any particulate carbonaceous material which has heretofore been employed to manufacture activated carbon is continuously slowly fed by, for example, a screw feeder into one or both tail pipes 3 and 3a through conduits 10 and 10a, respectively.

Pulsating hot gases in the tail pipes entrain the particulate feedstock and propel it back and forth within and between the pipes. At the juncture of the pipes within plenum 4, the pressure is positive, and a net flow of gas containing entrained par-

ticles of product is continually allowed to pass out of the system into the plenum 4 and then through conduit 11 to a cyclone separator 12. Activated carbon is collected in vessel 13 below the separator while gas is taken off at conduit 14.

Although the tail pipes are shown with their open ends spaced apart from another, these ends could be integrated together with an exit conduit extending therefrom so as to provide greater control over the residence time of the particles in the activation zone.

During activation in the tail pipes, the feedstock undergoes several changes which have heretofore been accomplished in a plurality of units. That is, the particles are substantially dried out and they lose some of their volatile matter to create pores on the particle surface. Thereafter the pore surface reacts with steam and/or CO₂. When as-mined lignite is employed as the feed material, there is sufficient moisture present in the feedstock to accomplish this latter reaction in the hot tail pipes. However, some particulate feedstocks such as subbituminous coal do not contain sufficient moisture, and it is then necessary to inject steam and/or CO₂ along with the feedstock. One manner of employing steam, for example, is to mix water with the feedstock and introduce it as a slurry. Another method is to employ part of a combustion zone or zones in the system as a steam generator wherein a water tube runs through the air inlet 9 and/or 9a into the respective combustion chamber, and opens into the tail pipe section. Alternatively, the combustion chamber can be surrounded by a coil or jacket for steam generation after which the steam is injected into the tail pipes. A further alternative involves injecting a granular material together with the feedstock, which material decomposes at the operating temperatures to steam and/or carbon dioxide. Still further, moisture can be supplied if a solid, moisture containing material is employed as the jet fuel.

For any particular dual pulse-jet structure, the amount of jet fuel which is supplied the system affects the operating temperatures and, thereby, product quality. Further, the continual rate at which the particulate feedstock is injected affects the gas-to-solids ratio in the "activation" zone. Product quality is also affected by the rate at which gas and entrained product are removed from the tail pipes. Optimum operating conditions are best determined experimentally for each feedstock and structure.

As indicated previously, pulse-jets operate on liquid, gaseous and solid fuels. A discussion of solid fuel operations is given in preprint No. WA69FU4 of the A.S.M.E., for the 1969 Winter Annual meeting of A.S.M.E. at Los Angeles, California, November, 1969 which preprint is entitled "Operating Experience with Lignite Fueled Pulse-Jets." Other fuels include propane, gasoline, oil, or bituminous coal.

The following example illustrates the effectiveness of the process of the present invention.

EXAMPLE

Two identical pulse-jets, each similar to the one described in "International Coal Preparation Congress", Fifth Congress, Pittsburgh, Pa., October 3-7, 1966, page 465, FIG. 1, were arranged with the openings in the tail pipes opposite one another and spaced apart 6 inches. A 55 gallon plenum vessel surrounded the juncture of the two pipes and the vessel had a 4 inch conduit leading to a cyclone separator.

Pulsating combustion was established with propane supplied at 15 psig through a manifold system to the combustion chambers. Lignite was then supplied at a rate of about 200 No./hr to one of the tail pipes at a point 6 feet from the open end of the pipe. The particle size of the lignite was about one-eighth inch and finer. Activated carbon product was collected at the cyclone separator at a rate of about 70 lb per hr. Some fine carbon was lost in the discharge gases.

Several tests were conducted with various lignites having a composition ranging from 29 percent moisture and 29 percent volatile matter to lignite char having essentially 0 percent moisture and 20.0 percent volatile matter MAF. To effect

temperature variations during the tests, the jet fuel inlet pressure was controlled by valves in the lines to each engine. Only the exit gas temperature at the juncture of the tail pipes was measured during the tests, although much higher temperatures obviously occurred within the shock waves in the pipes.

Satisfactory results were obtained in all these tests. As an example, when employing lignite having 29 percent moisture and 29 percent volatile matter, wherein the jet fuel was introduced at such a rate so that the temperature of the gas exiting from the plenum vessel was 1,100° F, the product had only 0.3 percent moisture and 28 percent volatile matter MAF. Using the iodine absorption test for activation evaluation, the product compared favorably with industrial-grade activated carbon. In additional tests, optimum results were obtained when moisture-containing char was slurried in water and then introduced into the pulse-jets.

Treating the feedstock in a pulsating atmosphere of hot gases has several advantages. First, the gas-particle relative velocity changes sweep the particle surface allowing increased heat and mass exchange. Further, pressure oscillations have a pumping effect on the volatiles within the particles which helps to partially remove such volatiles from the particles. Still further, very high temperatures occur within each shock wave although the nominal gas temperature may remain low. This latter "phenomena" is discussed in the *Journal of the Institute of Fuel*, September, 1961, pages 359-367.

By employing a dual-pulsed system as opposed to a single pulse jet, several advantages accrue. For example, the feedstock particles are not immediately expelled, and they thus have a high probability of many transits from one tail pipe to another so that sufficient residence time is encountered to accomplish the desired reactions. Further, dual pulse-jet engines mutually reinforce the pressure waves of one another which intensifies the above-mentioned pressure oscillations, and produces higher peak temperatures in the shock waves. Further, the magnitude of the gas-particle relative velocity changes is increased by more intense pulsations since such increases in intensity will raise the acceleration experienced by the feedstock particles either by simple translational motions or by being spun in velocity gradients.

In the prior art, several units have often been employed,

sometimes batch units, to produce activated carbon, involving residence times of several hours. In comparison, the single stage, continuous system of the present invention rapidly produces activated carbon. Low cost pulse-jet engines deliver extremely high heat release rates, and the pulsating flow allows this intense heat to be rapidly transferred to the feedstock. Thus, by the present invention, activated carbon can be produced on a large scale at low costs and is thus suitable for applications which have heretofore not employed activated carbon because of economics. For example, *Extension Bulletin E-668*, September, 1969, of the Michigan State University Cooperative Extension Service describes the use of activated carbon as a "food" for cows to prevent pesticide contamination in milk and meat. In the bulletin it was recognized that such treatment would be at a high cost considering the then prevailing price of the activated carbon.

The present invention, furthermore, would broaden the use of lignite (a little used national resource) and other coals as well.

What is claimed is:

1. In a process for producing activated carbon from a solid particulate carbonaceous feedstock the improvement comprising entraining said feedstock in the oscillating hot combustion gas in the tail pipes of a dual pulse jet combustion system in the presence of steam or CO₂; withdrawing from said system, at the juncture of said tail pipes, a gas containing entrained particles of activated carbon; and separating said activated carbon from said withdrawn gas.

2. The process of claim 1 wherein said feedstock is lignite.

3. The process of claim 1 wherein said feedstock is slurried in water when supplied to said tailpipes.

4. The process of claim 1 wherein said pulse-jet system is employed to generate steam, and then said steam is injected into said tailpipes.

5. The process of claim 1 wherein a granular material, which decomposes into steam or CO₂ at the temperature of said hot combustion gas, is injected into said tailpipes with said feedstock.

6. The process of claim 3 wherein said feedstock is lignite.

7. The process of claim 4 wherein said feedstock is lignite.

8. The process of claim 5 wherein said feedstock is lignite.

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