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(54) APPARATUS FOR THE PREPARATION OF ACTIVATED CARBON

(71) We, TAKEDA YAKUHI KOGYO KABUSHIKI KAISHA, also known as TAKEDA CHEMICAL INDUSTRIES LTD., a Japanese Body Corporate, of 27 Doshomachi 2-chome, Higashi-ku, Osaka, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to apparatus for the preparation of activated carbon from carbonaceous substances and, more particularly, to a shaft kiln having therein a reactor chamber partitioned into a plurality of serially communicated activation compartments or zones.

A multi-stage fluidized reactor for the preparation of activated carbon is well known in the art. Generally, the conventional multi-stage fluidized reactor comprises a plurality of up-standing activation tubes or stages, each two adjacent stages communicating by means of an overflow tube and the first and last stages being connected to a supply duct and a delivery duct respectively. The overflow tube connecting two stages is connected at one end to an upper portion of the interior of the first stage and at the other end to a lower portion of the interior of the subsequent stage so that the carbonaceous material being activated in the first mentioned stage overflows through said overflow tube into the subsequent stage. In this manner, the material to be activated, after being fed into the first stage, passes through each of the subsequent activation stages until it is discharged as activated carbon from the lower portion of the last activation stage.

It appears that the conventional multi-stage fluidized reactor of the type referred to above functions satisfactorily, but is relatively complicated in structure and therefore construction thereof cannot be easily performed. In addition, due to the arrangement wherein the upstanding activation tubes are arranged in a substantially circular configuration surround-

ing a heat nozzle it is very difficult to remodel the reactor to reduce or increase the number of activation stages thereby to enable the reactor to produce activated carbon of different qualities.

In our co-pending Application Number 14316/74 (Patent Specification No. 1,434,314) there is described and claimed an apparatus, for preparing activated carbon, comprising a shaft kiln with a vertical cavity therein and a perforated gas flow distributor which divides the cavity into a reactor chamber and a combustion chamber. The reactor chamber only is further divided into a plurality of compartments for activation.

According to the present invention there is provided apparatus for preparing activated carbon from carbonaceous material for activation with a gaseous activating medium which comprises in combination: a shaft kiln having a vertically upstanding cavity formed therein; a perforated horizontal gas flow distributor housed within said cavity and dividing said cavity into a reactor chamber and a combustion chamber, in use, the said horizontal gas flow distributor distributing the gaseous activating medium upwards from the combustion chamber to the reactor chamber; first vertical dividing means dividing said reactor chamber into a plurality of activation compartments, said dividing means having at least one passage communicating between said activation compartments through which the said carbonaceous material flows from the first to the final compartment; means connected to the first activation compartment for supplying the carbonaceous material at a constant rate therein; means connected to the final activation compartment for removing the carbonaceous material in the form of activated carbon therefrom; second vertical dividing means for dividing said combustion chamber into combustion compartments one immediately below each activation compartment; separate fuel burners and steam injectors connected to each combustion compartment for heating masses of

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carbonaceous material in said activation compartments; means for supplying the gaseous activating medium to the combustion chamber; and means for discharging gases emitted during the activation process from the individual activation compartments to the atmosphere.

Preferably, the first vertical dividing means and the second vertical dividing means are partition walls. Accordingly, in a particular embodiment of the present invention the apparatus has a reactor chamber formed therein which is divided into a plurality of, for example, three activation compartments by means of partition walls. The first and second or intermediate compartments and the second or intermediate and third or last activation compartments are respectively connected by openings formed in the partition walls between the first and intermediate activation compartments and between the intermediate and last activation compartments.

Furthermore, the volume of the activation compartments can be varied whereby the residence time of the carbonaceous material in each compartment can be kept substantially constant.

In the particular embodiment described above the activation reactor also has a combustion chamber formed therein immediately below the reactor chamber with a perforated gas flow distributor interposed between said reactor chamber and said combustion chamber. This combustion chamber is also divided by similar partition walls into combustion compartments corresponding in number to the activation compartments in the reactor chamber, one combustion compartment immediately below one activation compartment.

These combustion compartments are isolated from each other and steam injectors and fuel burners are provided one for each combustion compartment for effecting activation under individually controlled conditions.

The opening or passage formed in each partition wall within the reactor chamber is preferably in the form of a tunnel of circular cross section, said tunnel preferably being downwardly inclined towards a subsequent one of the activation compartments from the preceding activation compartment.

The apparatus of the present invention will be more fully described by way of specific example and with reference to the accompanying drawings, in which:

Figure 1 is a schematic side sectional view of an activation reactor in accordance with the present invention for the preparation of activated carbon.

Figure 2 is a cross sectional view taken along the line II—II in Figure 1.

Figure 3 is a schematic perspective view of one of the partition walls within a reactor chamber of the activation reactor of Figure 1, and

Figure 4 is a similar view to Figure 3, but

showing a modification of a passage formed in the partition wall of Figure 3.

Referring now to the accompanying drawings, the apparatus comprises a shaft kiln 10 having a cavity formed therein which is divided by a perforated gas flow distributor 13 into a reactor chamber 11 and a combustion chamber 12. As illustrated in Figure 2, the reactor chamber 11 is further divided into first, intermediate and last activation compartments 11a, 11b and 11c by three partition walls 14a, 14b and 14c which may be of a one-piece construction. Preferably, in order to facilitate remodelling of the apparatus in such a way as to increase or decrease the number of the activation compartments within the reactor chamber 11, these partition walls 14a, 14b and 14c are each made of a plurality of refractory blocks while the shaft kiln 10 is formed with an access opening or door (not shown) through which one or more workers can enter the reactor chamber 11.

These partition walls 14a, 14b and 14c each have a lowermost face resting on the gas flow distributor 13 and an uppermost face terminating substantially adjacent to the top of the reactor chamber 11 and, in the illustrated embodiment, are arranged in a substantially Y-shaped configuration as shown in Figure 2.

Of these partition walls, the walls 14b and 14c between the first and intermediate activation compartments 11a and 11b and between the intermediate and last activation compartments 11b and 11c, respectively, have passages 15a and 15b each formed in a lower portion of the corresponding partition wall adjacent to the distributor 13. As illustrated in Figure 3, each of these passages 15a and 15b in the partition walls 14b and 14c is preferably in the form of a tunnel of substantially circular cross-section, but may, if desired, be in the form of a tunnel of any other suitable cross-section.

A screw conveyor 16, which may be replaced by an endless belt conveyor or any other suitable conveyance, and which opens through the shaft kiln 10 into the first activation compartment 11a charges said compartment 11a at a constant rate with the carbonaceous material which is to be activated from a hopper 17. The carbonaceous material is introduced into the first activation compartment 11a from the hopper 17 through the screw conveyor 16 and passes through the passage 15a into the intermediate activation compartment 11b and then through the passage 15b into the last activation compartment 11c while it is fluidized and gradually activated in such a manner as will be described later. The carbonaceous material that passes into the last activation compartment 11c overflows as activated carbon into an overflow duct 18 formed in the shaft kiln 10. The overflow duct has one end open to the last activation compartment 11c and the other end suitably connected to a

collection container (not shown). It should be noted that the supply port in the shaft kiln 10 which communicates with the screw conveyor 16 should be situated above the level of the first mentioned open end of the overflow duct 18.

The individual activation compartments 11a, 11b and 11c communicate with the atmosphere through a common exhaust duct 19 outwardly extending from the top of the shaft kiln 10 for the discharge of gases emitted from these compartments during the activation process.

The combustion chamber 12 immediately below the reactor chamber 11 is also divided into combustion compartments 12a, 12b and 12c, two of which are shown in Figure 1, by the corresponding number of partition walls 20a, 20b and 20c (only one of which is shown in section in Figure 1), one combustion compartment for each activation compartment. These combustion compartments 12a, 12b and 12c respectively communicate with individual fuel burners 21a, 21b and 21c through flame nozzles 10a, 10b and 10c formed in the shaft kiln 10, each of said fuel burners 21a, 21b and 21c being adapted to heat the carbonaceous material in the corresponding activation compartment to a required temperature by a blast of flame emerging therefrom onto the corresponding combustion compartment.

These combustion compartments 12a, 12b and 12c also communicate with the respective steam injectors 22a, 22b and 22c through individual steam ducts 23a, 23b and 23c open towards the associated combustion compartments 12a, 12b and 12c. These steam injectors 22a, 22b and 22c in turn communicate with a common source of steam through steam pipes 24a, 24b and 24c and also to a common source of air through air ducts 25a, 25b and 25c, respectively, and also communicate with the exhaust duct 19 through respective manifolds 26a, 26b and 26c for directing portions of the discharge gases passing through the exhaust duct 19 onto the steam injectors 22a, 22b and 22c whereby, by the effect of a pressure differential, the heat energy of the discharge gases can be utilized to heat the steam.

It should be noted that the flame nozzle 10b, the burner 21b, the injector 22b and the ducts 23b, 24b and 25b are not shown in the accompanying drawings.

As illustrated in Figure 2, the activation compartments 11a, 11b and 11c have different volumes gradually decreasing in the order from the first activation compartment 11a to the last activation compartment 11c. The activation conditions in these compartments 11a, 11b and 11c are preferably maintained uniform. If the volumes of the compartments 11a, 11b and 11c are not individually selected in having regard to the reduction in apparent specific gravity and particle size, the result is

that the fluidized mass of carbonaceous material in each of the subsequent stages, i.e., in each of the intermediate and last activation compartments 11b and 11c will not be properly and sufficiently activated.

There is a possibility that a portion of the carbonaceous material entering an activation compartment passes into the subsequent compartment without being sufficiently fluidized in the preceding compartment. To avoid this possibility, each of the passages 15a and 15b respectively formed in the partition walls 14b and 14c should have at both ends thereof openings flush with the opposed surface of the partition wall 14b and 14c, each of said openings of said passages 15a and 15b being so sized as to occupy an area within the range of 1/30 to 1/20 of the surface area of the portion of either surface of the partition walls 14b and 14c that contacts the carbonaceous material being activated in any of the compartments 11a, 11b and 11c, and also being positioned approximately half-way across the corresponding partition wall and adjacent the bottom thereof. Alternatively, in the case where each passage 15a and 15b is employed in the form of a rectangular tunnel as shown in Figure 4, it should also have a ratio of the width to the height within the range of 3:1 to 1:3, preferably within the range of 3:2 to 1:2 in addition to the above requirement.

If the area of each opening of the passages 15a and 15b is greater than 1/20 of the surface area of the portion of either surface of the partition wall that contacts the carbonaceous material being fluidized in the corresponding activation compartment, the rate of activation in terms of percentage of particles of the carbonaceous material sufficiently activated relative to the percentage insufficiently activated and/or not activated will decrease and, therefore, this leads to a deleterious effect on product quality. On the other hand, if the area of said each opening thereof is smaller than the 1/30 limit, blockage will take place in passage 15a or 15b and, therefore, flow of the carbonaceous material from one activation compartment to the subsequent activation compartment will be hampered.

Moreover, in addition to the foregoing requirement the passage in each partition wall within the reactor chamber 11 should be downwardly inclined towards a subsequent activation compartment from the preceding one at an angle of from 45° to 50° relative to the plane at right angles to that of either surface of said partition wall within the reactor chamber 11.

In order to ensure a uniform activation in each of these activation compartments 11a, 11b and 11c, the uppermost levels of the fluidized masses of the carbonaceous material in the respective compartments 11a, 11b and 11c, which are preferably equal to or lower than 1/2 of the height of each partition wall

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- 4a, 14b or 14c, should be substantially equal to each other. This may be easily achieved by successively flowing the carbonaceous material through these activation compartments 11a, 11b and 11c, while raw material and activated carbon are continuously fed from the hopper 17 through the conveyor 16 and removed from the last activation compartment 11c through the overflow duct 18, respectively, in such a manner that the amount of carbonaceous material supplied is sufficient to compensate for the amount of activated carbon emerging from the last activation compartment 11c as the finished product.
- Fluidization of each mass of carbonaceous material in the corresponding activation compartment is effected by the upward flow of individual streams of a heated gaseous activating medium from the combustion compartment 12a, 12b or 12c to the exhaust duct 19 through the perforated gas flow distributor 13 while the carbonaceous material in each activation compartment is heated to such a temperature that activation of the material with the gaseous activating medium takes place.

More specifically, the rate of flow of each stream of the gaseous activating medium upward through the corresponding one of the

activation compartments may be selected so that the fluidization velocity in each activation compartment is within the range of 60 to 70 cm. per second depending upon the particle size distribution, but irrespective of the number of the activation compartments. By the term "fluidization velocity" is meant the superficial velocity of the gaseous activating medium. Alternatively, the activation compartments 11a, 11b and 11c may have different fluidization velocities if so desired or required.

The carbonaceous material referred to herein may be any material suitable for the preparation of activated carbon, for example, non-caking coal, carbonized lignite, carbonized vegetable material such as coconut shells, pecan hulls, wood and fruit pips, petroleum coke and bone char, and may have a particle size within the range of from 26 to 42 mesh Tyler standard series in order that it may be fluidized within each activation compartment. The gaseous activating medium referred to herein may be oxygen, air, steam, carbon dioxide or a mixture thereof, although steam is preferred.

The following table illustrates how various parameters vary according to the number of activation compartments within the reactor chamber 11.

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TABLE

Number of Activation Compartments

	2	3	4
Type of Raw Material	coconut shell	coconut shell	coconut shell
Rate of Supply	280-320 Kg/hr	220-250 Kg/hr	180-220 kg/hr
Apparent Specific Gravity of Raw Material	668-675 g/lit.	668-675 g/lit.	668-675 g/lit.
Rate of Removal of Activated Carbon	180-200 kg/hr	110-130 kg/hr	60-70 kg/hr
Apparent Specific Gravity of Activated Carbon	570-580 g/lit.	530-540 g/lit.	440-460 g/lit.
Product Quality:			
Acetone Adsorption	23.1-23.8%	26.8-27.7%	34.7-35.1%
Fluidization Velocity	60-70 cm/sec.	60-70 cm/sec.	60-70 cm/sec.
Average Residence Time	2 hr.	3 hr.	4 hr.
Temperature:			
1st Act. Compartment	820-830°C	830-840°C	840-850°C
2nd Act. Compartment	840-850°C	850-860°C	860-870°C
3rd Act. Compartment	—	860-880°C	870-890°C
Last Act. Compartment	—	—	890-910°C
Diameter of Passage in each Partition Wall Within Reactor Chamber	20 cm.	20 cm.	20 cm.
Ratio of Opening Area of Passage Relative to Contact Surface Area of Each Partition Wall Within Reactor Chamber	1/30	1/30	1/30
Position of Passage in Each Partition Wall Within Reactor Chamber	Half-way across and adjacent the bottom of the partition wall		
Angle of Inclination of Passage in Each Partition Wall Within Reactor Chamber	45°	45°	45°

From the foregoing description, it will be seen that activated carbon of relatively high quality may be obtained using multi-stage activation within a single activation reactor. Furthermore, remodelling of the reactor in such a way as to increase or decrease the number of activation compartments may be easily carried out since the partition walls dividing the reactor chamber into a plurality of

activation compartments may each be made of refractory bricks.

Although the present invention has been fully described by way of the preferred embodiment, it should be noted that various changes and modifications may be made thereto. For example, although in the preferred embodiment the partition walls 14a, 14b and 14c have been described as arranged in the sub-

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stantially Y-shaped configuration, they may be arranged in parallel relation to each other in a linear direction. In this case, the partition walls within the combustion chamber 12 should be correspondingly re-arranged.

WHAT WE CLAIM IS:—

1. Apparatus for preparing activated carbon from carbonaceous material by activation with a gaseous activating medium which comprises in combination:

a shaft kiln having a vertically upstanding cavity formed therein;

a perforated horizontal gas flow distributor housed within said cavity and dividing said cavity into a reactor chamber and a combustion chamber, in use, the said horizontal gas flow distributor distributing the gaseous activating medium upwards from the combustion chamber to the reactor chamber;

first vertical dividing means dividing said reactor chamber into a plurality of activation compartments, said dividing means having at least one passage communicating between said activation compartments through which the said carbonaceous material flows from the first to the final compartment;

means connected to the first activation compartment for supplying the carbonaceous material at a constant rate thereinto;

means connected to the final activation compartment for removing the carbonaceous material in the form of activated carbon therefrom;

second vertical dividing means for dividing said combustion chamber into combustion compartments one immediately below each activation compartment;

separate fuel burners and steam injectors connected to each combustion compartment for heating the masses of carbonaceous material in said activation compartments;

means for supplying the gaseous activating medium to the combustion compartment;

means for discharging gases emitted during the activation process from the individual activation compartments to the atmosphere.

2. Apparatus as claimed in claim 1 wherein said passage is formed substantially adjacent the bottom of the first vertical dividing means, said passage being downwardly inclined at an angle of from 45° to 50° relative to the plane transverse to the plane to either surface of said partition wall.

3. Apparatus as claimed in claim 1 or claim 2 wherein said removing means comprises an overflow duct having one end open to the final activation compartment and the other end open to a suitable collecting container.

4. Apparatus as claimed in claim 2 wherein the opening at each of the open ends of said passage has a surface area corresponding to 1/20 to 1/30 of the surface area of the portion of either surface of the first vertical dividing means that contacts the mass of carbonaceous material within the corresponding activation compartment.

5. Apparatus as claimed in claim 4 wherein the said passage is rectangular in shape and has a ratio of the width to the height within the range of 3:1 to 1:3.

6. Apparatus as claimed in claim 5 wherein the ratio of the width to the height is within the range of 3:2 to 1:2.

7. Apparatus as claimed in any one of the preceding claims further comprising recovery means connected between said discharge means and said separate supplying means for recovering a portion of the discharge gases present in said discharging means, thereby utilizing the intrinsic heat energy of said discharge gases to heat said gaseous activating medium.

8. Apparatus as claimed in claim 1 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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stantially Y-shaped configuration, they may be arranged in parallel relation to each other in a linear direction. In this case, the partition walls within the combustion chamber 12 should be correspondingly re-arranged.

WHAT WE CLAIM IS:—

1. Apparatus for preparing activated carbon from carbonaceous material by activation with a gaseous activating medium which comprises in combination:

10 a shaft kiln having a vertically upstanding cavity formed therein;

15 a perforated horizontal gas flow distributor housed within said cavity and dividing said cavity into a reactor chamber and a combustion chamber, in use, the said horizontal gas flow distributor distributing the gaseous activating medium upwards from the combustion chamber to the reactor chamber;

20 first vertical dividing means dividing said reactor chamber into a plurality of activation compartments, said dividing means having at least one passage communicating between said activation compartments through which the said carbonaceous material flows from the first to the final compartment;

25 means connected to the first activation compartment for supplying the carbonaceous material at a constant rate thereinto;

30 means connected to the final activation compartment for removing the carbonaceous material in the form of activated carbon therefrom;

35 second vertical dividing means for dividing said combustion chamber into combustion compartments one immediately below each activation compartment;

40 separate fuel burners and steam injectors connected to each combustion compartment for heating the masses of carbonaceous material in said activation compartments;

means for supplying the gaseous activating medium to the combustion compartment;

45 means for discharging gases emitted during the activation process from the individual activation compartments to the atmosphere.

2. Apparatus as claimed in claim 1 wherein said passage is formed substantially adjacent the bottom of the first vertical dividing means, said passage being downwardly inclined at an angle of from 45° to 50° relative to the plane transverse to the plane to either surface of said partition wall.

3. Apparatus as claimed in claim 1 or claim 2 wherein said removing means comprises an overflow duct having one end open to the final activation compartment and the other end open to a suitable collecting container.

4. Apparatus as claimed in claim 2 wherein the opening at each of the open ends of said passage has a surface area corresponding to 1/20 to 1/30 of the surface area of the portion of either surface of the first vertical dividing means that contacts the mass of carbonaceous material within the corresponding activation compartment.

5. Apparatus as claimed in claim 4 wherein the said passage is rectangular in shape and had a ratio of the width to the height within the range of 3:1 to 1:3.

6. Apparatus as claimed in claim 5 wherein the ratio of the width to the height is within the range of 3:2 to 1:2.

7. Apparatus as claimed in any one of the preceding claims further comprising recovery means connected between said discharge means and said separate supplying means for recovering a portion of the discharge gases present in said discharging means, thereby utilizing the intrinsic heat energy of said discharge gases to heat said gaseous activating medium.

8. Apparatus as claimed in claim 1 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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