

Description

The present invention relates to apparatus for contacting a particulate solid with a fluid in an elongate, substantially vertical treatment vessel, and to a method for continuously treating solid matter with a treatment fluid under high pressure in such a vessel. More particularly, the invention relates to such apparatus, and methods of using such apparatus, which apparatus includes means for periodically moving solids downwardly through the vessel for treatment while a treatment fluid continuously passes through the vessel under high pressure.

Solids-fluid contacting equipment is, of course, well known. One of the problems associated with such equipment is the entrainment of solids with the treating fluid and the carrying away of such solids with the treating fluid. Such solids often cause problems, and considerable effort is often taken to deal with them, such as by filtering the solids from the fluid. Filtration is perfectly feasible in some systems. However, in others, filtration is difficult and expensive.

A particular problem has arisen in this respect in the decaffeination of green coffee beans. In a well known commercial process, a batch of green coffee beans is introduced into a vessel, and supercritical carbon dioxide is passed through the vessel to effect decaffeination of the green beans. The supercritical fluid, bearing caffeine and leaving the vessel, is then processed, such as with charcoal, to remove the caffeine. The now caffeine-free supercritical fluid is returned to the vessel. During the entire operation, the circulating carbon dioxide is maintained under extremely high pressure, keeping the carbon dioxide in a supercritical state. The green coffee beans include a considerable amount of chaff. As the beans are processed, some of the chaff is entrained with the supercritical fluid and passes with the supercritical fluid into the supercritical carbon dioxide loop. The amount of entrained chaff is reduced by flowing the carbon dioxide downwardly through the bed. Chaff which does become entrained becomes separated as the carbon dioxide passes through the charcoal bed. As a preliminary step the raw beans may be subjected to chaff removal. Despite such preliminary chaff removal, however, a considerable amount of chaff enters the system with the beans and a considerable amount of chaff will be entrained in the circulating carbon dioxide. After each batch is completed, chaff is removed with the charcoal in which it has accumulated.

A continuous operation for the decaffeination of green coffee beans utilizing supercritical carbon dioxide has been developed and is disclosed in U.S. Patent No. 4,820,537 issued to Saul N. Katz, the disclosure of which is incorporated herein by reference. In this process, moistened green coffee beans are moved periodically downwardly, in pulses, through a substantially vertical column, while continuously flow-

ing supercritical carbon dioxide upwardly through the column. Unlike the batch process, the flow of supercritical carbon dioxide in the continuous process is not periodically interrupted, and unlike the batch process, the supercritical fluid circulates in its high pressure loop at substantially constant temperature and pressure. Moreover, the system is not intended to be shut down often, and both shutting down and starting up the system require a considerable amount of time. It will be understood that chaff which enters the system with the moistened beans and which becomes entrained in the supercritical dioxide will continuously build up in the system. This build-up can cause serious problems such as the need to shut down the process. Clearly, steps must be taken to deal with any chaff which flows out of the column with the supercritical fluid.

Filters, of course, could be used. However, it has been found that such filtration is extremely inefficient and expensive to put into practice. It has been found, for example, that a filter becomes highly plugged with chaff in a very short time.

Various types of filter are known. For example, EP-A-0318161 and US-A-4931180 describe a self-cleaning filtering apparatus with an inner filtering basket, the inside of which is kept clean by rotary scrapers. US-A-3385753 discloses a strainer for separating liquid from a wood-chip liquid mixture with a plurality of slot elements defining narrow slots of increasing width in the direction of the outlet.

In GB-A-2144056 there is described a screening element to form part of a screening drum of a hammer mill. This comprises a plurality of bars defining a part-cylindrical screening face.

It is an object of the present invention to provide, in a method and apparatus for contacting a particulate solid with a fluid in a treatment vessel, means for removing, in an efficient manner, chaff or other solids which becomes entrained in the treatment fluid as it passes through the treatment vessel.

The foregoing and other objects which will be apparent to those ordinary skill in the art are achieved in accordance with the present invention by modifying apparatus for contacting a particulate solid with a fluid. The apparatus comprises an elongate column for holding a bed of particulate solids for contact with a fluid. The column is designed to be oriented substantially vertically in use and has a fluid inlet near the bottom thereof for admitting a fluid into the column and a fluid outlet near the top thereof for permitting the fluid to exit from the column after passing upwardly through a bed of particulate solids in the column. In accordance with the invention, this apparatus is provided with a screen for screening solids from the fluid exiting the column through the fluid outlet, the screen comprising a plurality of vertical screen wires. The screen is located within the column adjacent the fluid outlet and is positioned such that all of the fluid pass-

ing through the column passes through the screen and thence through the fluid outlet. Each pair of adjacent vertical screen wires defines a substantially vertical screen slot therebetween, the width of each vertical screen slot being such as to screen solids from the exiting fluid and the length of each slot being many times its width, preferably at least ten times its width, and more preferably at least 25 or 50 times its width. Each wire is preferably substantially tapered, in its cross section, inwardly in a direction away from its upstream surface, the term "upstream" being in the sense of the direction of flow of the fluid through the screen. Thus, the slot width is preferably greater at the downstream surface of the screen than at its upstream surface. The screen wires are preferably wedge-shaped in cross section. A method in accordance with the invention comprises continuously treating solid matter with a treatment fluid under high pressure in a substantially vertical column through which a treatment fluid moves continuously upwardly through a bed of solid particulate matter in the column and then exits the column through a fluid outlet at the top of the column. Particulate solids are periodically pulsed downwardly through the column with fresh solids being introduced into the top of the column and with treated solids being discharged from the bottom of the column. The treatment fluid moves continuously through the column, and at high pressure. In accordance with the invention, a screen as described above is positioned in the column to screen solids from the fluid exiting the column. The screen is cleaned by the movement of the particulate high pressure solid matter as it is pushed downwardly through the column, thus avoiding the need to interrupt the high pressure process in order to clean the screen.

There follows a detailed description of preferred embodiments of the invention including the drawings in which:

Figure 1 is a diagrammatic side elevation view of apparatus for contacting a particulate solid with a fluid and including a screen in accordance with the invention within the column adjacent the fluid outlet at the top of the column;

Figure 2 is an enlarged diagrammatic side elevation view of a screen element which can be employed to make up the screen shown in Figure 1; Figure 3 is a diagrammatic sectional view of a screen element taken along the lines 3-3 of Figure 2; and

Figure 4 is an enlarged diagrammatic elevational sectional view of the top portion of the column of Figure 1 showing details of the manner of mounting a screen in the column.

Referring to Figure 1, apparatus for contacting a particulate solid with a fluid comprises an elongate column or pressure vessel 10. The vessel is suitable for holding a bed of particulate solids, not shown in Figure 1, for treatment with a fluid flowing through the

column. In use, the vessel is designed to be oriented substantially vertically and has a fluid inlet 11 at its lower end for admitting a fluid. A sparger 12, or the like, may be used for this purpose. The vessel also includes a fluid outlet 13 near the top of the column for permitting the fluid to exit the column after passing upwardly through the bed of particulate solids.

In accordance with the invention, a screen 14 is provided within the column, at its upper end, and adjacent to the fluid outlet. The screen is positioned such that all of the fluid which passes upwardly through the column passes through the screen and thence through outlet 13. The screen comprises a plurality of screen wires 15 which are vertical in the sense that they are oriented vertically when the column is positioned vertically for use as shown in Figure 1. Thus, the screen wires are substantially parallel with the longitudinal axis of the elongate columnar vessel.

The vessel shown in Figure 1 is cylindrical as is the screen 14 which is positioned concentrically within the cylindrical vessel and spaced inwardly therefrom such that an annular gap 16 or space, which serves as a collection plenum for fluid flowing through outlet 13, is present between screen 14 and inner wall 17 of vessel 10. Screen 14 is positioned in the column such that all of the fluid which passes upwardly through the column from inlet 12 passes through the screen and thereafter through fluid outlet 13. Although only one opening is shown in the fluid outlet, it will be understood that the fluid outlet can include any number of openings.

Screen 14 can be made up of one or more individual vertically stacked screen elements such as screen elements 18 and 19 shown in Figure 4. Such an arrangement enables a large screen to be mounted in a vessel where access to the vessel is through an opening smaller than the screen. This is particularly advantageous in large vessels designed to operate at high pressure and having a relatively small access opening. Figures 1-4 show a screen 14 which is made up of four semi-cylindrical screen elements, two of which, 18, 19, are shown in Figures 1 and 3. One of these, screen element 18, is illustrated in more detail in Figures 2 and 3. Prior to being mounted in cylindrical column 10, each screen element is shaped into semi-cylindrical form as shown in Figure 4.

Adjacent vertical screen wires define substantially vertical screen slots 20. The openings of each vertical screen slot at the upstream surface of the screen has a width which is designed to screen solids from the exiting fluid, and which has a length which is substantially greater than its width at its upstream surface. In general, the length of each slot is preferably at least ten times its width, and more preferably at least 25 or 50 times its length. The maximum length of each slot is determined primarily by practical considerations of fabrication of the screen and by a de-

sired total screen opening. In general, a slot length of about 50 to 200 times slot width is suitable. The individual wires are sufficiently massive to maintain slot width substantially uniformly along each slot. Where the slots are relatively long and the individual wires are relatively small in cross section, reinforcing elements may be secured to the wires, such as by welding, in order to maintain the adjacent screen wires substantially parallel to one another. As mentioned above, the terms "upstream" and "downstream" are used in the sense of the direction of the flow of the fluid through the screen. Thus, the "upstream" surface of the screen shown in Figure 1 is the innermost surface of the screen in the column.

As shown most clearly in Figure 2, each screen element is conveniently made up of an exterior frame 21, rectangular in configuration, and having vertical frame members 22, 23 and horizontal frame members 24, 25. Backing bars 26, 27 are provided as necessary to maintain proper spacing between screen wires 15.

As shown most clearly in Figure 4, screen 14 is supported in the column by being mounted on a cylindrical perforated support plate 28 which is itself concentrically mounted within the column by lower and upper support plates 29 and 30. As in the case of screen 14, the screen supporting structure may be assembled in its location in the column, such as by welding. Support members 28, 29, and 30 together support the screen in the upper portion of the column in such a manner that all of the fluid rising through the column passes through the screen and thence through outlet 13. Lower support plate 29 is an annular, imperforate plate located near the bottom of cylindrical perforated support plate 28. Upper support plate 30 is also annular and imperforate and is preferably frusto-conical in cross section as shown to facilitate downward motion of particulate solid matter through the column.

Screens 18 and 19, each of which is semi-circular in configuration in this embodiment, are mounted on perforate support plate 28 by bolts, by welding or by other suitable means. Two additional semi-circular screen elements (not shown) are also mounted on perforated support plate 28, thus completing the mounting of cylindrical screen 14 in the upper portion of the column. The column, of course, is provided with a suitable access opening to permit mounting of the screen and its supporting elements in the column. The various elements making up the screen and support members 28, 29 and 30 can be assembled in place, such as by welding. It is not necessary for the screen member or its support to extend completely around the periphery of the column.

Wires 15 making up the screen are preferably wedge shaped in cross section as shown in Figure 3. This ensures that the screen opening at the downstream face of the screen is larger than the screen

opening at the upstream face of the screen. It is also preferred that the upstream surface of the screen wires and of the screen itself is substantially planar as shown. This facilitates the cleansing action of the solid particulate matter as it flows downwardly across the face of the screen.

As shown in Figure 4, the screen is mounted adjacent the inner surface of the vertical wall of the vessel such that the downstream surface of the screen is spaced inwardly from the inner surface of the vessel wall.

The invention has particular utility in cylindrical vessels designed for continuous operation at high pressure. In these vessels, the screen is preferably mounted substantially concentrically within the cylindrical vessel such that an annular gap is formed between the screen and the inner cylindrical surface of the vessel.

As mentioned above, the screen may be made up of a plurality of discrete screen members, and this is particularly convenient when the screen is large, and even more so when a large vessel is designed for operating under high pressure. Conveniently, the discrete screen members can be cylindrical, or they may be segments of a cylinder, or both. In the illustrated embodiment, for example, two cylindrical screen elements are utilized, each of which is made up of a semi-circular, arcuate segment.

The screen wires 15 should be sufficiently robust to retain the wire spacing under operating conditions. The opening between the screen wires is designed to prevent solids above a particular size from passing through the screen and exiting with the fluid through outlet 13.

As mentioned above, the invention has particular utility in equipment designed to operate continuously under high operating pressure while periodically moving a particulate solid into the top of the column, downwardly through the column, and out through the bottom of the column. A method and apparatus of this type is described in the Katz patent mentioned above and is diagrammatically indicated in Figure 1 herein. In a typical process at steady state operating conditions, vessel 10 is substantially filled with a bed of moistened green coffee beans. An essentially caffeine-free supercritical fluid, such as supercritical carbon dioxide, is introduced through inlet 11, 12 and flows upwardly through the bed of coffee beans in the column. Caffeine-containing supercritical fluid is withdrawn from the upper end of the extraction vessel through outlet 13. Moistened green coffee beans are periodically admitted through a valve 31 into a blow case 32. Valves 33 and 34 are simultaneously opened so as to charge the moistened green coffee from blow case 32 into the upper end of the extraction vessel 10 and to discharge a portion of substantially decaffeinated green coffee beans from the lower end of the extraction vessel 10 to blow case 35. Valves 33 and 34

are then closed. Valve 36 is then opened to discharge the substantially decaffeinated green coffee from blow case 35. Additional green coffee is admitted through valve 31 into blow case 32, and the procedure is repeated.

As the coffee is being pulsed downwardly through the column in the manner just mentioned, the supercritical fluid continues to flow, at high pressure, through the column. In a typical operation, supercritical carbon dioxide flows through the column at a pressure of about 250 atmospheres (about 253 bar). As the beans move downwardly during each pulse, their movement across the surface of the screen cleans the screen, thus removing chaff which has built up on the screen during the period of operation between each excessive downward pulse. Thus, the column can be maintained in continuous operation without the need of mechanical means to scrape the column, or without the need of backflushing the screen such as by directing a fluid flow through the screen from its downstream surface to its upstream surface. It is a distinct advantage of the invention that such complex and inherently troublesome devices can be avoided.

Upper support plate 30, which is frusto-conical in configuration, acts as a funnel, directing downwardly moving particulate solids inwardly towards the surface of screen 14, which accelerates the downward movement of the solid particles as they are pulsed downwardly through the column. It is therefore preferred that the upper surface of plate 30 is smooth and oriented at an angle of not more than about 45°, preferably about 15-40°, with the column wall. The upstream surface of screen 14 is also preferably smooth and straight to facilitate the cleaning of the screen during the downward movement of the particulate solids.

In a preferred embodiment, in which screen 14 is utilized in a column which is about 100 feet (30.48 m) in height and about six feet (1.83 m) in diameter, screen 14 is cylindrical and has a height of about 2 feet (0.61 m) and a diameter of about 5 feet (1.52 m). Thus the screen is spaced inwardly of the column wall a distance equal to about 8% of the column diameter. In general, it is preferred that the screen is spaced inwardly about 3% to about 15% and more preferably about 5% to 10%, based on the column diameter. The screen is made up of two cylindrical sections, each about one foot (0.30 m) in height, with each cylindrical section being made up of three arcuate segments of equal length. The screen wires of each screen segment extend the full height of each screen segment. The slot width between wires is suitable for retention of the chaff from green coffee beans and a slot width of about 0.015 to 0.060 inches (0.38 to 1.52 mm) is appropriate for this purpose. The total open area of each screen segment is about 0.5 to 5 square feet (0.046 to 0.46 m²). The total open area of the screen is substantially greater than the cross sectional area of outlet 13, e.g. at least two times greater preferably ten to

100 times greater. The height of the screen can vary considerably, but a height which is about 1/4 to 2 times the inside diameter of the column will suffice. The total open area of the screen is suitably 1/10 to 2 times or higher, preferably about 1/4 to 5 times, more preferably 1/2 to 3 times, the cross sectional area of the column.

The width between adjacent wires preferably increases in the downstream direction, the individual slots between screen wires thus tapering outwardly. Thus, each screen wire, in cross section, preferably tapers inwardly in the direction of flow of the fluid through the screen and may be substantially wedge-shaped in cross section as shown in Figure 3. Suitable size of such wedge-shaped wire is about 0.030 to 0.150 in. (0.76 to 3.81 mm) in width, tapering at an angle of about 3-30°. The advantages of the present screen arrangement, particularly in continuous, high pressure apparatus, will be thus readily apparent.

Claims

1. An apparatus for contacting a particulate solid with a fluid comprising:

an elongate column (10) for holding a bed of particulate solids for contact with a fluid therein, said column being designed to be oriented substantially vertically in use and having a fluid inlet (11) near the bottom thereof for continuously admitting a fluid into the column (10) and a fluid outlet (13) near the top thereof for permitting the fluid to exit the column after passing upwardly through a bed of particulate solids therein;

solids admission means (31, 32, 33) for periodically admitting a portion of particulate solids to an upper end of the column (10); and

solids discharge means (34, 35, 36) for periodically discharging a portion of particulate solids from a lower end of the column (10);

said solids admission means (31, 32, 33) and said solids discharge means (34, 35, 36) being arranged to operate so that particulate solids are moved periodically downwardly, in pulses, through the column (10);

characterised in that said apparatus further comprises:

a screen (14) for screening solids from the fluid exiting the column (10) through said fluid outlet (13), said screen comprising a plurality of vertical screen wires (15) arranged parallel to one another, said screen (14) being located within said column (10) adjacent said fluid outlet (13) such that all of the fluid passing through the column (10) passes through said screen (14) and thence through said fluid outlet (13), each pair of adjacent vertical screen wires (15) defining a substantially vertical screen slot (20) therebetween.



are then closed. Valve 36 is then opened to discharge the substantially decaffeinated green coffee from blow case 35. Additional green coffee is admitted through valve 31 into blow case 32, and the procedure is repeated.

As the coffee is being pulsed downwardly through the column in the manner just mentioned, the supercritical fluid continues to flow, at high pressure, through the column. In a typical operation, supercritical carbon dioxide flows through the column at a pressure of about 250 atmospheres (about 253 bar). As the beans move downwardly during each pulse, their movement across the surface of the screen cleans the screen, thus removing chaff which has built up on the screen during the period of operation between each excessive downward pulse. Thus, the column can be maintained in continuous operation without the need of mechanical means to scrape the column, or without the need of backflushing the screen such as by directing a fluid flow through the screen from its downstream surface to its upstream surface. It is a distinct advantage of the invention that such complex and inherently troublesome devices can be avoided.

Upper support plate 30, which is frusto-conical in configuration, acts as a funnel, directing downwardly moving particulate solids inwardly towards the surface of screen 14, which accelerates the downward movement of the solid particles as they are pulsed downwardly through the column. It is therefore preferred that the upper surface of plate 30 is smooth and oriented at an angle of not more than about 45°, preferably about 15-40°, with the column wall. The upstream surface of screen 14 is also preferably smooth and straight to facilitate the cleaning of the screen during the downward movement of the particulate solids.

In a preferred embodiment, in which screen 14 is utilized in a column which is about 100 feet (30.48 m) in height and about six feet (1.83 m) in diameter, screen 14 is cylindrical and has a height of about 2 feet (0.61 m) and a diameter of about 5 feet (1.52 m). Thus the screen is spaced inwardly of the column wall a distance equal to about 8% of the column diameter. In general, it is preferred that the screen is spaced inwardly about 3% to about 15% and more preferably about 5% to 10%, based on the column diameter. The screen is made up of two cylindrical sections, each about one foot (0.30 m) in height, with each cylindrical section being made up of three arcuate segments of equal length. The screen wires of each screen segment extend the full height of each screen segment. The slot width between wires is suitable for retention of the chaff from green coffee beans and a slot width of about 0.015 to 0.060 inches (0.38 to 1.52 mm) is appropriate for this purpose. The total open area of each screen segment is about 0.5 to 5 square feet (0.046 to 0.46 m²). The total open area of the screen is substantially greater than the cross sectional area of outlet 13, e.g. at least two times greater preferably ten to

100 times greater. The height of the screen can vary considerably, but a height which is about 1/4 to 2 times the inside diameter of the column will suffice. The total open area of the screen is suitably 1/10 to 2 times or higher, preferably about 1/4 to 5 times, more preferably 1/2 to 3 times, the cross sectional area of the column.

The width between adjacent wires preferably increases in the downstream direction, the individual slots between screen wires thus tapering outwardly. Thus, each screen wire, in cross section, preferably tapers inwardly in the direction of flow of the fluid through the screen and may be substantially wedge-shaped in cross section as shown in Figure 3. Suitable size of such wedge-shaped wire is about 0.030 to 0.150 in. (0.76 to 3.81 mm) in width, tapering at an angle of about 3-30°. The advantages of the present screen arrangement, particularly in continuous, high pressure apparatus, will be thus readily apparent.

Claims

1. An apparatus for contacting a particulate solid with a fluid comprising:
 - an elongate column (10) for holding a bed of particulate solids for contact with a fluid therein, said column being designed to be oriented substantially vertically in use and having a fluid inlet (11) near the bottom thereof for continuously admitting a fluid into the column (10) and a fluid outlet (13) near the top thereof for permitting the fluid to exit the column after passing upwardly through a bed of particulate solids therein;
 - solids admission means (31, 32, 33) for periodically admitting a portion of particulate solids to an upper end of the column (10); and
 - solids discharge means (34, 35, 36) for periodically discharging a portion of particulate solids from a lower end of the column (10);
 - said solids admission means (31, 32, 33) and said solids discharge means (34, 35, 36) being arranged to operate so that particulate solids are moved periodically downwardly, in pulses, through the column (10);
 - characterised in that said apparatus further comprises:
 - a screen (14) for screening solids from the fluid exiting the column (10) through said fluid outlet (13), said screen comprising a plurality of vertical screen wires (15) arranged parallel to one another, said screen (14) being located within said column (10) adjacent said fluid outlet (13) such that all of the fluid passing through the column (10) passes through said screen (14) and thence through said fluid outlet (13), each pair of adjacent vertical screen wires (15) defining a substantially vertical screen slot (20) therebetween;

een, the opening of each vertical screen slot (20) at the surface of the screen (14) which is upstream in the sense of a fluid flowing through the column (10), passing through said screen (14), and exiting through said outlet (13) during operation of the column (10), having a width suitable for screening solids from the exiting fluid and having a length which is at least ten times its width, said screen (14) being cleaned by the movement of the particulate solids as the bed of particulate solids is periodically moved downwardly, in pulses, through the column (10).

2. Apparatus according to claim 1, characterised in that the width of each respective one of said vertical slots (20) at the upstream surface of said screen (14) is narrower than the width of said respective slot (20) at the downstream surface of said screen (14).

3. Apparatus according to claim 1 or claim 2, characterised in that said column (10) comprises a substantially cylindrical vertical wall (17) and that said screen (14) is mounted adjacent the inner cylindrical surface of said column wall (17) such that the downstream surface of said screen (14) is spaced inwardly from the inner cylindrical surface of the column wall (17).

4. Apparatus according to claim 3 characterised in that said screen (14) is substantially cylindrical and is mounted substantially concentrically within said cylindrical column (10) such that an annular gap (16) is formed between said screen (14) and the inner cylindrical surface of said column wall (17).

5. Apparatus according to claim 4, characterised in that it further comprises means for supporting said screen (14), said screen supporting means comprising a downwardly inwardly tapering frusto-conical member (30) secured to the inner cylindrical surface (17) of said column (10), said screen (14) being mounted at the lower end of said frusto-conical member (30).

6. Apparatus according to any one of claims 1 to 5, characterised in that said screen (14) comprises a plurality of screen members (18, 19), each of said screen members comprising a plurality of said vertical screen wires (15) and vertical slots (20).

7. Apparatus according to claim 6, characterised in that said screen (14) comprises a plurality of vertically stacked cylindrical screen members (18, 19).

8. Apparatus according to claim 6, characterised in that said screen (14) comprises a plurality of screen members (18, 19) in the form of arcuate segments.

9. Apparatus according to any one of claims 1 to 8, characterised in that the total open area of said screen (14) is at least twice the cross sectional area of the opening of the fluid outlet (13).

10. Apparatus according to any one of claims 1 to 9, characterised in that the vertical height of said screen (14) is from about one fourth to two times the inside diameter of the column (10).

11. Apparatus according to any one of claims 1 to 10, characterised in that the total open area of the screen (14) is from one tenth to two times the cross sectional area of the column (10).

12. Apparatus according to any one of claims 1 to 11, characterised in that it further comprises means for passing said fluid through said column (10) at an elevated operating pressure and for periodically moving a particulate solid into the top of the column (10) downwardly through the column (10), and out through the bottom of the column (10), while continuously passing said fluid through said column (10) under said elevated operating pressure.

13. A method of continuously treating solid matter with a treatment fluid under high pressure in a substantially vertical column (10) through which a treatment fluid runs continuously upwardly through a bed of solid particulate matter in said column (10) and then exits the column (10) through a fluid outlet (13) at the top of the column (10) and through which column particulate solids are pulsed periodically downwardly therethrough, with fresh solids being periodically introduced into the top of the column (10) and treated solids being discharged from the bottom of the column (10), the treatment fluid in the column being at said high pressure during operation of the column; characterised in that it further comprises:

providing a screen (14) in said column (10), said screen comprising a plurality of vertical parallel screen wires (15), said screen being located within said column (10) adjacent said fluid outlet (13) and positioned such that all of the fluid passing through the column (10) passes through said screen (14) and thence through said fluid outlet (13), each pair of adjacent parallel vertical screen wires (15) defining a substantially vertical screen slot (20) therebetween, the opening of each vertical screen slot (20) at the surface of the screen (14) which is upstream in the sense of a



fluid flowing through the column (10) and exiting through said outlet (13) during operation of the column (10), having a width which is designed to screen solids from the exiting fluid and having a length which is at least ten times its width at the upstream surface, whereby the screen (14) is periodically cleaned by the periodic movement of particulate solids downwardly through the column (10).

14. A method according to claim 13, characterised in that said particulate solids comprise coffee beans.

15. A method according to claim 14, characterised in that said coffee beans comprise green coffee beans and said fluid is supercritical carbon dioxide.

Patentansprüche

1. Vorrichtung zur Kontaktierung eines teilchenförmigen Feststoffs mit einem Strömungsmittel mit einer länglichen Kolonne (10) zur Aufnahme eines Bettes teilchenförmiger Feststoffe zwecks Berührung mit einem Strömungsmittel, wobei die Kolonne so ausgelegt ist, daß sie bei Benutzung im wesentlichen senkrecht orientiert ist, und einen Strömungsmiteleingang (11) nahe ihrem Boden zwecks kontinuierlicher Einführung des Strömungsmittels in die Kolonne (10) und einen Strömungsmittelausgang (13) nahe an ihrem kopf hat, damit das Strömungsmittel nach Durchgang durch das teilchenförmige Feststoffbett in Aufwärtsrichtung austreten kann,

Feststoffzuführungsmitteln (31, 32, 33) für die periodische Zuführung eines Quantums feinteiliger Feststoffe zu dem oberen Ende der Kolonne (10), und

Feststoffaustragsmitteln (34, 35, 36) für periodischen Austrag eines Quantums feinteiliger Feststoffe aus dem unteren Ende der Kolonne (10),

wobei die Feststoffzuführungsmittel (31, 32, 33) und die Feststoffaustragsmittel (34, 35, 36) so angeordnet sind, daß im Betrieb die teilchenförmigen Feststoffe in Stößen periodisch abwärts durch die Kolonne (10) bewegt werden, dadurch gekennzeichnet, daß die Vorrichtung ferner ein Sieb (14) zum Absieben von Feststoffen aus dem die Kolonne (10) durch den Strömungsmittelausgang (13) verlassenden Strömungsmittel umfaßt, das Sieb eine Mehrzahl vertikaler, parallel zueinander angeordneter Siebdrähte (15) umfaßt, das Sieb (14) in der Kolonne (10) nahe dem Strömungsmittelausgang (13) so angeordnet ist, daß das gesamte durch die Ko-

lonne (10) gehende Strömungsmittel durch das Sieb (14) und daher durch den Strömungsmittelausgang (13) strömt, jedes Paar benachbarter vertikaler Siebdrähte (15) zwischen sich einen im wesentlichen vertikalen Siebschlitz (20) begrenzt, dessen Öffnung an der Oberfläche des Siebs (14), die beim Betrieb der Kolonne (10) auf der Anströmseite liegt bei einer Richtung des durch die Kolonne (10) strömenden, das Sieb (14) passierenden und durch den Ausgang (13) austretenden Strömungsmittels, eine zur Feststoffabscheidung aus dem austretenden Strömungsmittel geeignete Breite und eine wenigstens das Zehnfache ihrer Breite betragende Länge hat, wobei das Sieb (14) durch die Bewegung der teilchenförmigen Feststoffe gereinigt wird, während das teilchenförmige Feststoffbett in Stößen periodisch abwärts durch die Kolonne (10) bewegt wird.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Breite eines jeden vertikalen Schlitzes auf der Anströmfläche des Siebs (14) enger als die Breite des betreffenden Schlitzes (20) auf der Abströmfläche des Siebes (14) ist.

3. Vorrichtung nach Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß die Kolonne (10) eine im wesentlichen zylindrische, vertikale Wandung (17) umfaßt und daß das Sieb (14) an der inneren zylindrischen Oberfläche der Kolonnenwandung (17) so angebracht ist, daß die Abströmfläche des Siebs (14) von der inneren zylindrischen Oberfläche der Kolonnenwandung (17) nach innen auf Abstand gehalten ist.

4. Vorrichtung nach Anspruch 3, dadurch gekennzeichnet, daß das Sieb (14) im wesentlichen zylindrisch ist und im wesentlichen konzentrisch in der zylindrischen Kolonne (10) so angebracht ist, daß zwischen dem Sieb (14) und der inneren zylindrischen Oberfläche der Kolonnenwandung (17) ein ringförmiger Spalt (16) gebildet ist.

5. Vorrichtung nach Anspruch 4, dadurch gekennzeichnet, daß sie ferner Mittel zur Halterung des Siebes (14) umfaßt, die ein abwärts nach innen zulaufendes, kegelstumpfförmiges Teil (30) umfassen, das an der zylindrischen Innenfläche (17) der Kolonne (10) befestigt ist, wobei das Sieb (14) an dem unteren Ende des kegelstumpfförmigen Teils (30) angebracht ist.

6. Vorrichtung nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß das Sieb (14) eine Mehrzahl von Siebteilen (18, 19) umfaßt, von denen jedes eine Mehrzahl der genannten vertikalen Siebdrähte (15) und vertikalen Schlitzes (20)



umfaßt.

7. Vorrichtung nach Anspruch 6, dadurch gekennzeichnet, daß das Sieb (14) eine Mehrzahl senkrecht übereinander geschichteter, zylindrischer Siebteile (18, 19) umfaßt. 5
8. Vorrichtung nach Anspruch 6, dadurch gekennzeichnet, daß das Sieb (14) eine Mehrzahl von Siebteilen (18, 19) in Form bogenförmiger Segmente umfaßt. 10
9. Vorrichtung nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß die gesamte offene Fläche des Siebs (14) wenigstens das Zweifache der Querschnittsfläche der Öffnung des Strömungsmittelausgangs (13) beträgt. 15
10. Vorrichtung nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß die vertikale Höhe des Siebs (14) etwa ein Viertel bis zu dem Zweifachen des Innendurchmessers der Kolonne (10) beträgt. 20
11. Vorrichtung nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, daß die gesamte offene Fläche des Siebes (14) ein Zehntel bis zu dem Zweifachen der Querschnittsfläche der Kolonne (10) beträgt. 25
12. Vorrichtung nach einem der Ansprüche 1 bis 11, dadurch gekennzeichnet, daß sie ferner Mittel umfaßt, um das Strömungsmittel bei erhöhtem Betriebsdruck durch die Kolonne (10) zu leiten und einen teilchenförmigen Feststoff in den Kopf der Kolonne (10), abwärts durch die Kolonne (10) und durch den Boden der Kolonne (10) zu führen, während das Strömungsmittel unter dem erhöhten Betriebsdruck kontinuierlich durch die Kolonne (10) strömt. 30
13. Verfahren zur kontinuierlichen Behandlung eines festen Stoffes mit einem Behandlungsströmungsmittel unter hohem Druck in einer im wesentlichen senkrechten Kolonne (10), durch die das Behandlungsströmungsmittel kontinuierlich aufwärts durch ein teilchenförmiges Feststoffbett in der Kolonne (10) läuft und dann die Kolonne (10) am Kopf durch einen Strömungsmittelausgang (13) verläßt und durch die teilchenförmige Feststoffe periodisch abwärts gepulst werden, wobei frische Feststoffe periodisch in den Kopf der Kolonne (10) eingeführt und die behandelten Feststoffe vom Boden der Kolonne (10) ausgetragen werden, wobei das Behandlungsströmungsmittel in der Kolonne während des Kolonnenbetriebs unter dem hohen Druck steht, dadurch gekennzeichnet, daß man ferner in der 35

Kolonne (10) ein Sieb (14) mit einer Mehrzahl vertikaler paralleler Siebdrähte (15) vorsieht, das in der Kolonne (10) nahe an dem Strömungsmittelausgang (13) so angeordnet ist, daß das gesamte durch die Kolonne (10) strömende Strömungsmittel durch das Sieb (14) und dann durch den Strömungsmittelausgang (13) hindurchtritt, wobei jedes Paar benachbarter paralleler vertikaler Siebdrähte (15) zwischen sich einen im wesentlichen vertikalen Schlitz (20) begrenzt, dessen Öffnung an der Oberfläche des Siebs (14), die während des Betriebs der Kolonne (10) bei durch die Kolonne (10) strömendem und durch den Ausgang (13) austretendem Strömungsmittel auf der Anströmseite liegt, eine zur Feststoffabsiebung aus dem austretenden Strömungsmittel ausgelegte Breite und eine wenigstens seine zehnfache Breite auf der Anströmfläche aufweisende Länge hat, wodurch das Sieb (14) durch die periodische Abwärtsbewegung der teilchenförmigen Feststoffe durch die Kolonne (10) periodisch gereinigt wird.

14. Verfahren nach Anspruch 13, dadurch gekennzeichnet, daß die teilchenförmigen Feststoffe Kaffeebohnen umfassen.

15. Verfahren nach Anspruch 14, dadurch gekennzeichnet, daß die Kaffeebohnen grüne Kaffeebohnen sind und das Strömungsmittel überkritisches Kohlendioxid ist. 30

Revendications

1. Appareil destiné à mettre en contact une matière solide en particules avec un fluide, comportant :
une colonne allongée (10) destinée à maintenir un lit de matières solides en particules pour contact avec un fluide, ladite colonne étant conçue pour être orientée sensiblement verticalement en utilisation et ayant une entrée de fluide (11) à proximité du fond afin d'admettre en continu un fluide dans la colonne (10) et une sortie de fluide (13) à proximité du sommet afin de permettre au fluide de sortir de la colonne après passage vers le haut à travers un lit de matières solides en particules dans celle-ci;
des moyens d'admission de matières solides (31, 32, 33) destinés à admettre périodiquement une partie des matières solides en particules à une extrémité supérieure de la colonne (10);
et
des moyens d'évacuation de matières solides (34, 35, 36) destinés à évacuer périodiquement une partie des matières solides en particules à une extrémité inférieure de la colonne (10);
lesdits moyens d'admission de matières



solides (31, 32, 33) et lesdits moyens d'évacuation de matières solides (34, 35, 36) étant prévus pour fonctionner de telle sorte que les matières solides en particules sont déplacées périodiquement vers le bas, par impulsions, à travers la colonne (10);

caractérisé en ce que ledit appareil comporte en outre :

un crible (14) destiné à cribler des matières solides du fluide sortant de la colonne (10) par ladite sortie de fluide (13), ledit crible comportant plusieurs fils de crible verticaux (15) disposés parallèlement l'un à l'autre, ledit crible (14) se trouvant dans ladite colonne (10) de façon adjacente à ladite sortie de fluide (13) de telle sorte que tout le fluide passant à travers la colonne (10) passe à travers ledit crible (14) et ensuite par ladite sortie de fluide (13), chaque paire de fils de crible verticaux adjacents (15) définissant une fente de crible sensiblement verticale (20) entre eux, l'ouverture de chaque fente de crible verticale (20) au niveau de la surface du crible (14) qui est en amont dans le sens d'un écoulement de fluide à travers la colonne (10), en passant à travers ledit crible (14), et en sortant par ladite sortie (13) pendant le fonctionnement de la colonne (10), ayant une largeur appropriée pour cribler les matières solides du fluide qui sort et ayant une longueur qui est d'au moins dix fois sa largeur, ledit crible (14) étant nettoyé par le déplacement des matières solides en particules lorsque le lit de matières solides en particules est déplacé périodiquement vers le bas, par impulsions, à travers la colonne (10).

2. Appareil selon la revendication 1, caractérisé en ce que la largeur de chaque fente respective desdites fentes verticales (20) au niveau de la surface amont dudit crible (14) est plus étroite que la largeur de ladite fente respective (20) au niveau de la surface aval dudit crible (14).

3. Appareil selon la revendication 1 ou la revendication 2, caractérisé en ce que ladite colonne (10) comporte une paroi verticale sensiblement cylindrique (17) et en ce que ledit crible (14) est monté de façon adjacente à la surface cylindrique intérieure de ladite paroi de colonne (17) de telle sorte que la surface aval dudit crible (14) est espacée vers l'intérieur de la surface cylindrique intérieure de la paroi de colonne (17).

4. Appareil selon la revendication 3, caractérisé en ce que ledit crible (14) est sensiblement cylindrique et est monté de manière sensiblement concentrique à l'intérieur de ladite colonne cylindrique (10) de telle sorte qu'un vide annulaire (16) est formé entre ledit crible (14) et la surface

cylindrique intérieure de ladite paroi de colonne (17).

5. Appareil selon la revendication 4, caractérisé en ce qu'il comporte en outre des moyens destinés à supporter ledit crible (14), lesdits moyens de support de crible comportant un élément tronconique se rétrécissant vers l'intérieur (30) fixé à la surface cylindrique intérieure (17) de ladite colonne (10), ledit crible (14) étant monté à l'extrémité inférieure dudit élément tronconique (30).

6. Appareil selon l'une quelconque des revendications 1 à 5, caractérisé en ce que ledit crible (14) comporte plusieurs éléments de crible (18, 19), chacun desdits éléments de crible comportant plusieurs fils de crible verticaux (15) et fentes verticales (20).

7. Appareil selon la revendication 6, caractérisé en ce que ledit crible (14) comporte plusieurs éléments de crible cylindriques empilés verticalement (18, 19).

8. Appareil selon la revendication 6, caractérisé en ce que ledit crible (14) comporte plusieurs éléments de crible (18, 19) sous la forme de segments courbes.

9. Appareil selon l'une quelconque des revendications 1 à 8, caractérisé en ce que la surface ouverte totale dudit crible (14) est au moins le double de la section de l'ouverture de la sortie de fluide (13).

10. Appareil selon l'une quelconque des revendications 1 à 9, caractérisé en ce que la hauteur verticale dudit crible (14) est d'environ un quart à deux fois le diamètre intérieur de la colonne (10).

11. Appareil selon l'une quelconque des revendications 1 à 10, caractérisé en ce que la surface ouverte totale du crible (14) est de un dixième à deux fois la section de la colonne (10).

12. Appareil selon l'une quelconque des revendications 1 à 11, caractérisé en ce qu'il comporte en outre des moyens destinés à faire passer ledit fluide à travers ladite colonne (10) sous une pression de fonctionnement élevée et destinés à déplacer périodiquement une matière solide en particules dans le sommet de la colonne (10) vers le bas à travers la colonne (10), et vers l'extérieur à travers le fond de la colonne (10), tout en faisant passer continuellement ledit fluide à travers ladite colonne (10) sous ladite pression de fonctionnement élevée.



13. Procédé de traitement en continu d'une matière solide avec un fluide de traitement sous haute pression dans une colonne sensiblement verticale (10) à travers laquelle se déplace en continu vers le haut un fluide de traitement à travers un lit de matière solide en particules dans ladite colonne (10) et sort alors de la colonne (10) par une sortie de fluide (13) au sommet de la colonne (10) et les matières solides en particules sont périodiquement pulsées vers le bas à travers la colonne, avec des matières solides fraîches périodiquement introduites au sommet de la colonne (10) et des matières solides traitées qui sont évacuées par le fond de la colonne (10), le fluide de traitement dans la colonne étant sous ladite haute pression pendant le fonctionnement de la colonne;
- caractérisé en ce qu'il comporte en outre :
- le fait de prévoir un crible (14) dans ladite colonne (10), ledit crible comportant plusieurs fils de crible parallèles verticaux (15), ledit crible se trouvant dans ladite colonne (10) de façon adjacente à ladite sortie de fluide (13) et positionné de telle sorte que tout le fluide passant à travers la colonne (10) passe à travers ledit crible (14) et ensuite par ladite sortie de fluide (13), chaque paire de fils de crible parallèles verticaux adjacents (15) définissant une fente de crible sensiblement verticale (20) entre eux, l'ouverture de chaque fente de crible verticale (20) au niveau de la surface du crible (14) qui est en amont dans le sens d'un écoulement de fluide à travers la colonne (10) et en sortant par ladite sortie (13) pendant le fonctionnement de la colonne (10), ayant une largeur qui est conçue pour cribler les matières solides du fluide qui sort et ayant une longueur qui est d'au moins dix fois sa largeur au niveau de la surface amont, ledit crible (14) étant périodiquement nettoyé par le déplacement périodique des matières solides en particules vers le bas à travers la colonne (10).
14. Procédé selon la revendication 13, caractérisé en ce que lesdites matières solides en particules comprennent des grains de café.
15. Procédé selon la revendication 14, caractérisé en ce que lesdits grains de café comprennent des grains de café verts et ledit fluide est du dioxyde de carbone supercritique.

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