

PATENT SPECIFICATION (11)

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1543063

- (21) Application No. 20750/76 (22) Filed 19 May 1976 (19)
 (31) Convention Application No. 583 974 (32) Filed 5 June 1975 in
 (33) United States of America (US)
 (44) Complete Specification published 28 March 1979
 (51) INT. CL.⁷ B01D 29/24
 (52) Index at acceptance
 B1D 1104 1107 1201 1806 1819 1903 2001 2002 2003 2005
 2006 2104 2113 2303 AC LA
 B1F 4G
 B1Q 1 2

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(54) APPARATUS AND PROCESS FOR CONTINUOUS CONCENTRATION AND WASHING OF SOLIDS FROM A SOLIDS-CONTAINING FLUID

(71) We, ARTISAN INDUSTRIES INC., a corporation organised and existing under the laws of the State of Massachusetts, United States of America, of 73 Pond Street, Waltham, Massachusetts, United States of America, 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:—

This invention relates to an apparatus and process for continuous concentration and washing of solids from a solids-containing fluid.

Various types of filtration devices have heretofore been known for concentrating the solids content of a fluid. For example, U.S. Patent 3,437,208 describes a device wherein a solids-containing fluid is pumped under pressure across the filtering surfaces of assembled hollow filter members so that a portion of the fluid is passed through the filtering surfaces and into the supporting filter member structures. The fluid is thereafter removed as a filtrate, and solids tending to remain on the filtering surfaces during the filtering operation are continuously returned into the solids-containing fluid to increase the concentration of solids within the filtration device and thereby form a thickened slurry for subsequent removal from the device. U.S. Patent 3,437,208 also describes a series of filtering and washing steps utilizing the vessels of three separate filtration devices interconnected by conduits. Each of the filtration devices has a hollow shaft. The hollow shaft of the first filtration device carries off filtrate from the first vessel, and the second vessel is provided with a hollow shaft for discharging wash liquid as waste. Wash liquid from the third vessel, removed through the hollow shaft of the third vessel, is added to the second vessel and thus removed as waste through the hollow shaft of the second ves-

sel. Fresh wash liquid is added to an inlet in a conduit between the second and third vessels which carries the slurry output of the second vessel. U.S. Patent 3,437,208 indicates that for the described apparatus to be housed in a common vessel, partitions must be provided in the vessel as well as a hollow shaft with independent channels for carrying off the filtrate and the wash liquid.

In U.S. Patent 1,264,635 a filter and wash system is described in which six separate filter units are used. Three of the filter units separate sludge from filtrate and three are used as washers to wash the sludge. The three washer units are arranged in series with the first washer unit receiving all the sludge from the three filter units A, A¹, and A². Wash liquid in washer unit 1 is supplied by the liquid removed from washer unit 2. The wash liquid removed in washer unit 1 is then added to the unfiltered material passed through the filter units A, A¹, and A². The sludge in turn removed from washer unit 1 together with the wash liquid from washer unit 3 is then added to washer unit 2. The sludge from washer unit 2, together with the fresh wash water is then added to washer unit 3 from which the sludge is removed while the wash liquid is recycled to be added to the sludge coming from washer unit 1 and going into washer unit 2.

Means have also heretofore been known for cleaning an accumulation of solids material which has deposited on the surfaces of filtering diaphragms in filtration devices. In some instances, such filtration devices have been periodically dismantled to remove the filtering diaphragms for cleaning purposes. In other instances, a backwash arrangement has been used to wash the solids deposited on the filtering surfaces, for example, by means of water forced into and through the interior of a hollow filter and through the filtering diaphragms. In still other instances, such as is described in U.S.

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Patent 1,000,540, a filter cake has been produced in a centrifugal device by the centrifugal separation of the solids from the filtrate. Subsequent to the formation of the filter cake it is washed by adding wash water to the interior of the centrifuge through the same valve and piping as the centrifuge material. After the filter cake has been washed the machine is disassembled and the cleaned filter cake is removed from the machine. Each of these washing processes is a discontinuous process which requires a shutting down and dismantling of the apparatus.

Other examples of discontinuous processes are found in U.S. Patents 1,920,126 and 3,108,951. Thus, in U.S. Patent 1,920,126 solid material such as wax contained in wax-bearing mineral oil is separated in a filter press and washed with a solvent which is added within the interior of the filter press after the formation of the filter cake. The solvent addition is continued until the cake is completely washed. The press is then opened and the cake removed. In U.S. Patent 3,108,951 a filter cake in a centrifugal device is washed after formation of the cake within the centrifuge by the addition of wash water which is then centrifugally passed through the cake to wash the cake.

Apparatus is also known for refining oil, such as shown in U.S. Patent 956,065 in which liquids containing oil are forced through a plurality of screens which break up the liquid and separate the impurities therefrom. In that apparatus provision is also made for adding gas, air or other fluid material to carry out the purifying process for the liquid. Also, a method is described in U.S. Patent 3,346,418 for washing impurities from clay-like and jelly-like materials by continuous addition and removal of a liquid medium which is a solvent for the impurities, the removal occurring upon passage of the particle-carrying liquid through a porous tube.

Other processes are known for separating or extracting soluble impurities from a solid by counter-flowing a solvent through the solid material. These processes shown, for example, in U.S. Patents 2,547,577, 2,686,192, 2,998,307, 3,111,393 and 3,275,472 operate by adding a fresh solvent to the solids at the last stage of the extraction process, collecting that solvent and progressively adding, collecting, and introducing the contaminated solvent to the preceding stages of the process. The method of adding solvent operates to extract soluble material by counter-flowing the solvent through the material as it progresses through the device.

Thus, while many varied processes and devices has been proposed for either separating a solid, washing a solid, or extracting soluble material from a solid, no process or apparatus has heretofore been known for

preparing a washed concentrate from a solids-containing fluid by a continuous process in which the solids-containing fluid has the solids separated, concentrated and washed on a steady basis in a dynamic concentrator-washer within and incorporating a unitary housing.

According to the present invention there is provided a dynamic concentrator-washer for separating a filtrate and a concentrated slurry from a solids-containing fluid and washing the concentrated slurry with a wash fluid prior to discharge of the concentrated slurry from the concentrator-washer, the concentrator-washer comprising:

a housing defining an enclosure having a concentrating region and a washing region; a first inlet in said housing for the introduction into said enclosure of a pressurized solids-containing fluid;

a least one first annular element mounted within said concentrating region and having at least one radially extending surface thereon in the flow path of solids-containing fluid introduced into said enclosure through said first inlet;

a shaft mounted in said housing on the longitudinal axis of said housing and extending through said concentrating region and said washing region;

at least one first radially extending element mounted on said shaft within said concentrating region and having at least one radially extending surface thereon in the flow path of solids-containing fluid introduced into said enclosure through said first inlet, said radially extending surface of said first radially extending element extending radially outwardly of said longitudinal axis in substantially parallel, spaced apart relation to said radially extending surface of said first annular element towards an interior surface of said housing but terminating in spaced relation thereto sufficient for fluid flow therebetween;

said first annular element or said first radially extending element being a first filter element and said radially extending surface thereof being a filter surface disposed to pass a filtrate therethrough into the interior of said first filter element from solids-containing fluid within said concentrating region; a first outlet in said housing, said first outlet being connected to the interior of said first filter element for discharging filtrate from said concentrating region and said first filter element and thereby providing a concentrated slurry of solids-containing fluid in said concentrating region;

at least one second inlet in said housing, said second inlet communicating with said enclosure for the introduction into said enclosure of a wash fluid to provide a mix within said enclosure of the wash fluid and said concentrated slurry;

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at least one second annular element mounted within said washing region and having at least one radially extending surface thereon in the flow path of said mix of concentrated slurry and wash fluid;

at least one second radially extending element mounted on said shaft within said washing region and having at least one radially extending surface thereon in the flow path of said mix of concentrated slurry and wash fluid, said radially extending surface of said second radially extending element extending radially outwardly of said longitudinal axis in substantially parallel, spaced apart relation to said radially extending surface of said second annular element towards an interior surface of said housing but terminating in spaced relation thereto sufficient for fluid flow therebetween;

said second annular element or said second radially extending element being a second filter element and said radially extending surface thereof being a filter surface disposed to pass wash fluid from said mix of concentrated slurry and wash fluid therethrough into the interior of said second filter element;

a second outlet in said housing, said second outlet being connected to the interior of said second filter element for discharging wash fluid from said washing chamber and said second filter element and thereby providing a washed concentrated slurry in said washing region; and

a third outlet in said housing, said third outlet being in the flow path of said washed concentrated slurry to discharge said washed concentrated slurry from said housing;

said concentrator-washer being capable of having drive means coupled thereto for causing relative rotation between said shaft and with it said radially extending elements, and said annular elements.

According to the present invention there is also provided a dynamic process for continuously separating a concentrated slurry and a filtrate from a solids-containing fluid and washing undesired material from the concentrated slurry to provide a washed concentrated slurry, the process comprising the steps of:

introducing a solids-containing fluid under pressure into one end of an enclosed housing having said one end and another opposite end and containing (i) a plurality of serially arranged, spaced apart annular elements each having at least one radially extending surface disposed in a path wherealong fluid may flow through said housing from said one end to said other end thereof, and (ii) a shaft means including a plurality of radially extending elements arranged serially between successive ones of said annular elements in substantially parallel, spaced apart relation to said radially extending surfaces

thereof and terminating in spaced relation to an interior surface of said housing sufficient for fluid flow therebetween, each said radially extending element having at least one radially extending surface disposed in said path wherealong fluid may flow through said housing from said one end to said other end thereof, said annular elements or said radially extending elements being filter elements and said radially extending surfaces of said filter elements being filter surfaces, the interior of each said filter element being in fluid flow communication with the exterior of said housing;

flowing the solids-containing fluid past and against said filter surface of at least a first said filter element and thereby and thereat effecting a separation of filtrate from the solids-containing fluid and providing a concentrated slurry including some undesired material within said housing;

discharging the separated filtrate from the interior of said first filter element and said housing;

introducing wash fluid into said housing and intermixing the same therein with said concentrated slurry and included undesired material;

flowing the intermix of wash fluid, concentrated slurry and undesired material past and against said filter surface of at least a second filter element and thereby and thereat effecting a separation of wash fluid and undesired material from the concentrated slurry and providing a washed concentrated slurry within said housing;

discharging the separated wash fluid and undesired material from the interior of said second filter element and said housing;

discharging the washed concentrated slurry from said housing at said other end thereof; and

continuously effecting relative rotation between said shaft means and with it said radially extending elements, and said annular elements to impel a radial flow of both solids-containing fluid and the intermix of wash fluid, concentrated slurry and undesired material across said filter surfaces of said first and second filter elements respectively;

the process being such that slurry flows continuously from said one end to said opposite end of said housing through respective concentrating and washing regions in said housing, being concentrated and then washed as it flows progressively downstream.

Briefly, embodiments of the invention provide a concentrator-washer having separate concentrating and washing regions within a unitary housing. An inlet is provided in the housing for the introduction into the concentrating region of a pressurized solids-containing fluid and, downstream of the washing region, an outlet is provided in the

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housing for the discharge from the concentrator-washer of a concentrated slurry of washed solids. At least one inlet is also provided in the housing for the introduction of a wash fluid into the washing region. Moreover, in both the concentrating region and the washing region, at least one stationary or rotating filter element is provided in each region, each of the filter elements having at least one filtering surface and a suitable drainage system for the removal of a filtrate (in the concentrating region) and the wash fluid (in the washing region). Rotating or stationary discs are mounted between adjacent filter members. The concentrator-washer further has a rotor including a shaft which is rotatably mounted on a longitudinal axis within the concentrating and washing regions coaxially of the filter elements. If the design selected be one in which the filter elements rotate, the disc members may be mounted on the relatively stationary housing. Alternatively, if the filter members be mounted relatively stationary, the disc members may be mounted on the rotating shaft.

In the washing region after the wash fluid is introduced into the housing it is commingled with the concentrate to, for example, dissolve soluble impurities within the concentrate. At the same time the wash fluid may be considered to dilute the impurity-containing fluid present already and then that liquid or fluid as so diluted to be removed by a filtration step, thus reducing the amount of impurities remaining in the solution which wets the concentrate. A wash fluid outlet provided in and on the housing of the concentrator-washer drains the wash liquid therefrom as that liquid is mixed with original or vehicle liquid or fluid containing feed material impurities in the manner described. Embodiments of the invention may be employed to wash salts, an acid or an alkali out of the concentrate and, by way of further utility and example, may be employed also with a suitable solvent to wash an organic material such as tar out of the concentrate.

In one embodiment of the invention a unitary concentrator-washer is provided with a split rotor shaft wherein the concentrator portion of the apparatus has its rotating members coupled to one motor drive, and the washer portion of the apparatus has its rotating members coupled to a different motor drive. By this means greater or at least independently controllable motive power may be provided to the rotating members in the portion of the unit where the material being processed has the higher solids concentration, and thus is more viscous and resistive to flow. If desired, a single motor may be employed with a suitable transmission to provide different rotor speeds in the two portions of the unit.

In another embodiment of the invention a concentrator-washer has a plurality of filter elements and a plurality of rotatable discs disposed coaxially in an alternating manner about a rotatable shaft. The filter elements are of hollow construction to permit passage of filtrate and wash fluid through the filter. By arranging the filters and rotating discs in alternating positions and utilizing a plurality of blades or vanes upon the surface of the discs, those vanes projecting laterally towards the filtering surface of the adjacent filtering element and in the general direction of the longitudinal axis of the rotor, the solids-containing fluid progresses through the concentrating region of the concentrator-washer by passing through one stage formed between filtering elements to a downstream stage. As it progresses through the concentrating region, fluid is continuously removed as a filtrate from the on-flowing solids-containing material, and the thickened or concentrated solids are gradually dried in the sense of their vehicle fluid being filtered out. That dried material, while having fluid removed, may still contain insoluble or soluble, dissolved impurities.

To remove those impurities a washing region is provided within the apparatus having at least one solvent or wash fluid injection port mounted on the housing between a disc and filter element. By injecting the solvent or wash fluid into this stage of the washing region the sinuous path of the concentrate, coupled with the forces exerted upon the concentrate by the rotation of the discs and the stationary position of the filters, works or commingles the solvent or wash fluid into the concentrate and dissolves the soluble impurities in the concentrate. Downstream of the injection port the contaminated wash fluid is removed through a drainage port connected to the next filtering element and through the wash fluid outlets of the filter. Diluted originally present and impurity-containing liquid mixed with the wash fluid as described hereinbefore is removed also. Thus, the previously dried concentrate, now wetted by the wash fluid added through the wash fluid injection port, is passed over the filtering element, and the wash fluid is purged from the concentrate by the filter element.

In the manner just described the dried concentrate, momentarily reliquefied by the wash fluid, is returned to its original dry state by the filtering action of the next filter element in the washing region. Further, if washing fluid be continuously injected at the same rate as wash fluid is removed, a continuous operation may be obtained which washes but does not thin the concentrate being processed by the unit, i.e., a concentrate may be obtained which comprises solids in a cleaner fluid without a substan-

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tial change in the mass of the combined material. Still further, by using a wash fluid in which undesirable solid constituents of the concentrate are soluble, or which chemically reacts with undesirable solid constituents to produce a liquid or gaseous fluid, a concentrate may be obtained which is thinned as well as washed.

Depending upon the condition of the material, one or more solvent or wash fluid injection and removal or drainage ports may be needed. Further, in order to remove completely the added fluid it may be necessary to pass the material, subsequent to wash fluid addition, through one or more stages progressively removing the added fluid through the filter element at each stage.

The wash fluid removed in the washing region, depending upon the type of material, its condition and the nature of the impurities, may either be discarded or returned back into the washing region and used again as wash fluid, or alternatively, if required to thin or fluidize the feed material, may be added to the feed material in the concentrating region of the apparatus. Thus, in one embodiment the wash liquid is recycled to an earlier washing stage in the washing region, used as a wash liquid and then purged out of the concentrate. That fluid, now more contaminated than when originally added to the device, but still capable of dissolving impurities, is again injected into the device and flows into an earlier, more contaminated concentrate stage in the washing region. In that manner, by progressively advancing the wash fluid from one stage to an earlier stage, the wash fluid is continuously recycled and used over and over while the concentrate is simultaneously purged of fluids and purified of soluble impurities.

In summary, embodiments of the apparatus and process of the present invention separate solids from a solids-containing fluid and then "wash" the solids by use of one or more of the following particular processes which of course include the liquid or fluid mixing concept, i.e., dilution concept, for impurity reduction as explained above as well as the concept of impurity dissolution in or simple washing of the solids.

1. Injecting a substantial amount of fresh washing fluid at a single intermediate point in the washing region at which the concentrate has achieved approximately its desired degree of dryness, with that fluid and the undesired materials, e.g., salts, washed out by the fluid being removed from the washing region through the wash fluid drains from several downstream sections or stages following wringing out or expressing and, in effect, redrying operations on the rewetted concentrate in those sections or stages.

2. Injecting a limited amount of fresh washing fluid at each of a plurality of points

successively downstream beginning at about the same intermediate point as before, the amount injected at any particular point being essentially wrung out of the concentrate and drained from the washing region along with any undesired materials picked up by the wash fluid by the time the next injection point is reached so that the whole washing operation comprises alternating steps of limited rewetting and restoration drying.

3. Injecting a limited amount of fresh washing liquid close to the concentrate discharge end of the washing region where the concentrate has achieved approximately its desired degree of dryness; wringing out that liquid and its picked-up undesired material in at least one more operating stage of the washing region and draining the now somewhat contaminated wash fluid from the concentrator; injecting the wash fluid as so contaminated into the washing region at a point at least one section upstream from or above the point of its initial injection; wringing out that liquid with additional contaminant in the following section and draining it from the washer ahead of the point of initial injection; injecting the additionally contaminated wash fluid into the washer at a point at least one section ahead of the point of second injection, etc., etc., and in that way working upstream in counterflow fashion with injections of a limited amount of increasingly contaminated wash fluid.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a side elevation view, in cross-section, of an embodiment of concentrator-washer constructed according to this invention including a plurality of coaxially mounted rotor discs and interposed filter elements, and having wash fluid injection and removal ports;

FIG. 2 is an end elevation or face view, partly fragmented, of the grooved disc member of a filter element employed in the embodiment of FIG. 1 or 4;

FIG. 3 is a cross-section view of a filter element grooved disc taken along line 3—3 in FIG. 2 looking in the direction of the arrows;

FIG. 4 is a side elevation view, partly in cross-section and partly schematic, of another embodiment of concentrator-washer constructed according to this invention including a plurality of coaxially mounted rotor discs and interposed filter elements, and having wash fluid injection and removed ports with pumps arranged to provide a counter-current wash fluid flow path within the apparatus; and

FIG. 5 is an end elevation or face view of a radially extensive, rotary disc employed in the embodiment of FIG. 1 or 4.

Referring now to the drawings in detail,

the concentrator washer 11 illustrated in FIG. 1 is constructed with a composite or built-up housing 12 which bounds a concentrating region 14 and a washing region 38 within the housing 12. The concentrator-washer 11 is provided with a pair of end plates 16, 18 at its opposite ends, and the front end plate 16 is provided with an inlet port 20 and the rear end plate 18 is provided with an outlet port 22. In addition, the spigot for the outlet port 22 has mounted thereon a control valve 24, which may be a manually operated valve, for controlling the flow of material from the outlet spigot. The housing 12 shown in FIG. 1 is comprised of a series of spacer rings 26 each of which has an annular side 28 secured as by welding to one adjacent filter element 30, and an opposite annular side 32 which abuts another adjacent filter element 30. The spacer rings 26 and filter elements 30 are mounted in alternating fashion to define peripherally the concentrating and washing regions 14, 38 with each filter element 30 (except the filter element 30B nearest the rear end plate 18) having a spacer ring secured to it to form a unitary assemblage of a filter element 30 and an adjacent spacer ring 26.

As shown in FIG. 1, a wash fluid injection port 40 is provided on and in the concentrator-washer 11 passing through an immediately located spacer 26 into the washing region 38 which, like the concentrating region 14, is enclosed by the housing 12 of the concentrator-washer 11. Depending upon the type of material being processed and the operating characteristics desired for the concentrator-washer 11, single or multiple injection ports 40 may be provided in the washing region 38 downstream of the concentrating region 14. Solids-containing liquid or fluid material supplied to the concentrator-washer 11 through inlet port 20 will first be dried or concentrated by having a substantial amount of its vehicle fluid removed through the filter elements 30 in the concentrating region 14. Then the resulting concentrate will pass into the washing region 38 and past the wash fluid injection port 40 where the concentrate is diluted or reliquefied by wash fluid injected through the port 40.

Internally the concentrator-washer 11 shown in FIG. 1 has a rotor shaft 34 which passes through front end plate 16 of housing 12 and terminates within washing region 38 at a point spaced from rear end plate 18. A plurality of radially extension rotor discs 60 (FIG. 5) are mounted on rotor shaft 34 within the concentrating and washing regions 14, 38 in a secured manner to be rotated with the rotor shaft 34 as by a key 62. Rotor discs 60 are of solid, i.e., non-hollow, construction, and are disposed in alternating fashion with annular filter elements 30. Each rotor disc 60 other than rotor discs 60A and

60B nearest front end plate 16 and rear end plate 18 respectively is generally within a stage 36 of concentrating region 14 or washing region 38 bounded by a unitary assemblage of a filter element 30, a spacer ring 26 and a surface of an adjacent filter element 30. Each rotor disc 60 including rotor discs 60A and 60B is disc-like in general configuration with an outer diameter which is less than the inside diameter of concentric spacer rings 26. Further, each rotor disc 60, 60A and 60B is spaced longitudinally from the adjacent end wall 16 or 18 and/or from adjacent filter elements 30, 30A, 30B. This spacing helps provide a flow path for a solids-containing fluid from inlet port 20 through concentrating region 14 and washing region 38 to outlet port 22 of the concentrator-washer 11, that flow path being of a sinuous nature overall as generally indicated by arrows in FIG. 1.

A drive motor 46 is provided which is mounted on a frame 48 outside of housing 12. The motor 46 is coupled by V-belts 50 to a speed-control power transmission unit 52 also mounted on frame 48. Power transmission unit 52 is in turn connected to a drive shaft 54 which is coupled to rotor shaft 34 of concentrator-washer 11 through suitable bearings and seals. By means of motor 46 and transmission unit 52, which can be a manually controlled unit, the rotor shaft 34 may be driven at preselected speeds.

As shown in FIG. 5, each rotor disc 60 is secured as by welding to a collar 56 mounted on rotor shaft 34. Each rotor disc 60 is provided with four or more equally spaced blades or vanes 58, 58A on each of its radial surfaces which project from those respective surfaces towards adjacent filter elements 30 when the rotor disc 60 is in place in the housing 12 of the concentrator-washer 11. The blades 58, 58A each extend in a curved path from a point 70 adjacent but spaced apart from collar 56 to the outer periphery of the rotor disc 60. For any rotor disc 60 the curvilinear configuration of the blades 58 on one radial surface thereof is an image of the configuration of the blades 58A on the opposite surface of that rotor disc 60 as shown in FIG. 5. Each rotor disc 60 is mounted on rotor shaft 34 such that the impulse imparted to solids-containing fluid contacted by its blades 58, 58A corresponds in direction to advancing movement along the flow path on each side of the rotor disc 60 as indicated generally by arrows in FIG. 1. Thus for a given direction of rotation the blades on one side direct fluid outwardly of the rotor disc 60 while the blades on the opposite side direct fluid inwardly.

As shown in FIG. 1, the blades 58, 58A project laterally either towards an adjacent filter element 30 or an end plate 16, 18. As shown in FIG. 5, each rotor disc 60 has

four equally spaced fluid passages or openings 64 along its periphery adjacent to its collar or hub 56. Those passages 64 serve to permit a portion of the solids-containing fluid within concentrating region 14 to flow through rather than sinuously around the rotor discs 60. In other embodiments according to this invention passages 64 can be omitted or, alternatively, passages may be provided for flow of fluid elsewhere through the rotor discs 60, for example, adjacent to their outer peripheries, to vary the flow paths.

Each filter element 30 in both concentrating region 14 and washing region 38 comprises an annular disc shown especially in FIGS. 2 and 3 which is characterized by an opening 66 for passage therethrough of the rotor shaft 34. Opening 66 is sufficiently large to allow adequate process flow of solids-containing fluid between the inner periphery of the filter element 30 and the outer surface of the rotor shaft 34 and/or that of any hub or collar 56 on the rotor shaft 34. There are a pair of oppositely disposed lugs or ears 67 on each filter element 30 for providing vertical support and alignment of it and the entire filter element assembly of which it is a component on horizontal rails (not shown) of the structural framework in and on which the assembled housing 12 rests. Each filter element 30 is characterized further by a plurality of spaced-apart concentric grooves 68 on each face as well as a plurality of radial bores 90, such as for example three, which have outlet ports 82 and which communicate along the lengths of the bores 90 with grooves 68 through passages or openings 72. Each filter element 30, as an assembly, includes one or two filter surfaces formed, for example, by filter cloths as of polyester material secured on and to opposite sides of the grooved filter disc. For details of such assembly, not shown here, reference may be had especially to FIG. 5 of our United States Patent 3,884,805.

Referring to FIGS. 1 and 3, the ports 82 of the radial bores 90 are in fluid communication with drains 84 and 41 which extend into partitioned or isolated collection pans 86 and 86¹ respectively. The filtrate collection pan 86 for the concentrating region 14 has a discharge nozzle 88 extending outside the concentrator-washer 11 to carry off filtrate, with a valve 92 being provided to control the flow of filtrate from the concerned pan 86. As shown in FIG. 1, collection pan 86¹ for washing region 38 has a similar discharge nozzle 88¹ and control valve 92¹. The reason for providing separate, non-communicating drain or collection pans 86, 86¹ is that the material flowing out of drains 84 will be essentially just vehicle fluid while that flowing out of drains 41 will be a mixture of wash fluid, dissolved impurities and some residual vehicle fluid. It may well be

desirable to keep the materially different drainages isolated for recovery and re-use of at least one of them.

In FIG. 4 a further embodiment of this invention is illustrated in which parts which correspond to those of the embodiment of FIG. 1 are indicated by identical numbers. In the embodiment of FIG. 4 several wash fluid injection ports 40, 40A, 40B are provided in spaced relation along the length of the illustrated concentrator-washer 11 in its washing region 38 to enable a counter-current flow of wash fluid from one washing stage 36 of the washing region 38 to the adjacent upstream washing stage 36. In this embodiment drains 41, 41A are connected to each filter element 30, and pumps 42, 42A, 42B are provided on the drains 41, 41A from which it is desired to recirculate wash fluid to an adjacent upstream washing stage 36. In operation, fresh wash fluid is added to the concentrate through an injection port 40A nearest the concentrate discharge end of the apparatus having a valve 94 for controlling the rate of addition. The newly added wash fluid, together with vehicle fluid and any other fluid still present in the concentrate, is removed through the last filter element 30B in the washing region 38, and its drain 41A. This combined fluid is picked up and delivered by a pump 42A back through pipe 43 to the injection port 40B next upstream of the original wash fluid injection port 40A.

As shown in FIG. 4, the fluid injected or reinjected at port 40B is in turn removed through a drain next upstream of drain 41A; picked up and delivered by a pump 42B for injection into the immediately preceding washing stage 36; withdrawn through the drain 41 associated therewith, and then picked up and delivered by a pump 42 for injection into the next preceding washing stage 36, etc., etc. This process of injection and mixing, filtration and removal, pumping and reinjection may be continued as desired and the wash fluid injection and removal controlled as appropriate to the particular type of material being treated, or to the condition of the concentrate at the point at which the concentrate is advanced into washing region 38. The wash fluid finally removed from near the upstream end of the washing region 38 through drain 41B and its control valve 92B may be either discarded, treated for recovery of the impurities or treated for recovery of the fluid itself.

As shown in FIGS. 3 and 4, the filter element radial bores 90 and outlets 82 in the washing region 38 are connected to drains 41, 41A, etc., and pumps 42, 42A, 42B, etc. Piping 43 returns the wash fluid removed through filter element 30B to injection port 40B where it is recycled and commingled

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into the concentrate passing beneath that port. That fluid, mixed with and serving to dilute liquid or fluid present already in the concentrate, is in turn removed by the adjacent downstream filter element 30 and recycled through the appropriate bores 90, outlets 82, drains 41 and pump 42 back into the next preceding washing stage 36. This recycling procedure according to which wash fluid is worked upstream through successive washing stages 36 conserves wash fluid as it calls for repeated use of that fluid in the operation of the apparatus.

The concentrator-washer 11 of FIG. 4 is provided with a split rotor shaft 34, each portion of which has a separate motor drive. Thus, the drive motor M for the portion of the rotor shaft 34 within concentrating region 14 is separate from the drive motor M' for the portion of rotor shaft 34 within washing chamber 38 of the concentrator-washer 11. A suitable journal and bearing arrangement 102 interconnects the two portions of the rotor shaft 34 to provide mutual support and alignment for the facing ends of those shaft portions. By using separate drive mechanisms, the concentrating and washing functions of the apparatus may be controlled and regulated independently through different rates of rotation being imparted to the two segments or portions of the rotor shaft 34.

Reverting now particularly to the embodiment illustrated in FIG. 1 to describe the operation, a solids-containing fluid is supplied under pressure from and by pump 19 to inlet 20 for concentrator-washer 11. At the same time, rotor shaft 34 is caused to revolve by motor 46. The consequent rotation of rotor discs 60 and their blades 58 and 58A causes the major portion of the entering fluid to disperse about the initial rotor disc 60A, and thereafter follow a flow path which meanders sinuously about the stationary filter elements 30 and the remaining, interposed rotor discs 60, towards final rotor disc 60B and the concentrate outlet 22 of the concentrator-washer 11. Concurrently a minor portion of the solids-containing fluid flows essentially along the rotor shaft 34 through openings 64 in the rotor discs 60 (see FIG. 5). As the solids-containing fluid moves through concentrating region 14 around and across each successive filter element 30 in and adjacent to its flow path, its vehicle fluid component passes as a filtrate through the filtering surfaces of the filter elements 30, then out of the interior of the filter elements 30 through their radial bores 90 and outlets 82, and then into filtrate collection pan 86 from which it is removed through discharge nozzle 88.

When solids-containing fluid moves through concentrating region 14 it is processed sufficiently to form a thickened slurry of desired

concentration, say for example a slurry with 50% solids, and that concentrate is then washed within the washing region 38 of the unitary concentrator-washer 11. Thus, while filtrate was removed from the solids-containing material as it passed through the concentrating region 14, that material may still contain undesired fluid or particulated impurities. Water may be used as a wash fluid to remove salts from a concentrate, and suitable solvents may be used to wash out alkali, acids or an organic contaminant such as tar. Additionally, instead of being a solvent for the concerned impurity or contaminant the added wash fluid may be a reagent which will react chemically with the impurity to form a liquid or gaseous fluid which can be more readily removed, upon removal of contaminated wash fluid, than the original impurity can be. It is to be understood, of course, that in most if not all situations the aforescribed dilution effect will be significantly useful along with any dissolution or reaction effect.

The wash fluid added to washing region 38 of concentrator-washer 11 is commingled with through-flowing concentrated slurry by the action of rotor discs 60 within the washing region 38 and their blades 58 and 58A. This commingling permits the wash fluid to interact with and/or dilute the impurities or contaminants. The wash fluid added through wash fluid inlet 40 (FIG. 1) or 40A (FIG. 4) and commingled with the concentrate is subsequently removed, carrying undesired diluted, dissolved or reacted materials with it, from washing region 38 by being passed through filter elements 30 and out of the wash fluid drains 41. Then the wash fluid in an at least somewhat contaminated condition is either collected in a wash fluid collection pan 86¹ (FIG. 1) or delivered through pumps and pipes of the groups 42, 43 to earlier stages 36 in the washing region 38 (FIG. 4) except for fluid discharged through final drain 41B. In the latter instance, the addition, circulation and removal of wash fluid may be accomplished by utilizing control valves and positive pressure pumps 42, 42A, 42B et seq., on recycling pipes 43 interconnecting stages 36 of the composite washing region 38. Alternatively, pumps 42 for pipes 43 may be adjustable vacuum pumps which can be used to vary the rate of filtrate discharge from the filter elements 30 as well as control the recycling of the wash fluid.

As the operation of the concentrator-washer 11 continues, fresh pressurized solids-containing fluid is supplied steadily through inlet port 20 from pump 19 while filtrate from this fluid is removed from concentrating region 14 through filter elements 30 and drains 84. Fresh wash fluid is continuously supplied to washing region 38 of the unitary assembly through wash fluid injection port

(18)

40 (FIG. 1) or 40A (FIG. 4), while contaminated wash fluid is removed through wash fluid drains 41 (FIG. 1) or 41B (FIG. 4). A washed concentrated slurry is removed continuously through outlet 22 and its control valve 24.

The rate of feed of solids-containing fluid to inlet 20 is regulated by suitable controls on supply pump 19. The rate of feed of wash fluid to the wash fluid inlet 40 (FIG. 1) or 40A (FIG. 4) is determined by the setting of control valve 94. The rate of concentrate discharge from the unit is established and maintained according to the adjustment of aforementioned control valve 24 on outlet port 22. Valve 92 controls the rate of vehicle fluid flow from filtrate collection pan 86, while valve 94 regulates the rate of fresh wash fluid supply to washing chamber 38. Accordingly, in operation the settings of the designated valves control the concentration of the out-going slurry, and the mass balance is for steady-state running such that the out-flow rate of the washed concentrated slurry substantially equals the feed discharge rate of pump 19 minus the rate of filtrate output through valve 92. The wash fluid addition is generally completely removed during the washing process considered as a whole, and accordingly does not affect the mass balance to any usual, significant extent.

The filter elements 30 and spacer rings 26 form successive washing stages 36A, 36B, 36C and the like within the overall washing region 38, the successive stages 36 being bounded on either side by a surface of a filter element 30. A vacuum pump may be provided on one or more of the filtrate or wash fluid drains to increase the rate of discharge of wash fluid or filtrate by increasing the pressure difference across the filtering surfaces within the unit.

Referring to the embodiment of FIG. 1, solids-containing fluid flowing within concentrator-washer 11 travels through concentrating region 14 making a U-turn around the outer edge of rotor disc 60A and passing between that rotor disc 60A and the housing 12 and then moving inwardly along the downstream side of rotor disc 60A between it and filter element 30A. The solids-containing fluid then turns around the inner edge of filter element 30A between that filter element 30A and the rotor shaft 34 and passes outwardly between the downstream face of filter element 30A and the upstream face of the second rotor disc element 60, then around the outer periphery of the latter rotor disc 60 and so on sinuously and with increasing solids concentration through the concentrating region 14. When the concentrated slurry reaches washing region 38 of the unit it has lost much of its initial vehicle fluid content and in that sense has been dried.

As the concentrated slurry passes around

the outer edge of the first rotor disc 60 of the washing region 38, wash fluid flows into it through wash fluid inlet port 40. The fluid therethrough injected commingles with the concentrated slurry to dissolve the soluble impurities or chemically react with the impurities and thereby carry out any required purification of the concentrate, including dilution of contaminants already in liquid form. The wash fluid carrying contaminants with it is then filtered out in the washing region 38 through successive filter elements 30 as the concentrate is propelled along past them by upstream pump pressure and the mechanical energy input of the blades 58, 58A on opposite sides of the interposed rotor discs 60.

Because the concentration and washing of the feed material occur within one housing 12, great process flexibility is possible during the operation of the described apparatus. For example, the solids-containing fluid may be and is customarily contemplated to be pre-concentrated, i.e., substantially freed of its vehicle fluid content, in concentrating region 14 before it is washed or decontaminated in washing region 38. Alternatively, if the solids-containing fluid have a consistency which requires it, wash fluid inlet ports (not shown) may be provided through the spacers 26 of the housing 12 by way of concentrating region 14 so that wash fluid may be injected into the concentrating region 14 to commingle with and additionally fluidize the solids-containing fluid flowing through it. Further, if wash fluid be injected into the early stages of washing region 38 at the same rate as it is removed through those stages' filter elements 30 the fluidity of the concentrated slurry may be maintained at the same level until the last few stages of the washing region 38 where, if desired, the concentrate may be purged of fluid without any addition of new fluid, and the concentrated slurry thereby raised to its finally desired concentration of solids for discharge from the housing 12.

As another variation, wash fluid may be injected through alternate wash fluid injection ports 40 in the washing region 38, that is, ports spaced apart by at least two stages 36. The concentrated slurry will then have contaminated wash fluid and residual vehicle fluid, too, removed within not only the stage 36 in which the wash fluid is added but also at least the next adjacent stage 36 downstream. Thus the concentrate, while being washed by the addition of wash fluid in one stage 36, is dried within the next stage of the washing region 38. Accordingly, a concentrate which is still rather fluidized upon entry into the washing region 38 can be both washed and progressively dried while passing through the washing region 38 to provide a product concentrate at outlet 22 which is

both dried and washed as compared to the somewhat concentrated slurry first entering the washing region 38.

Because of the construction and operational attributes of the apparatus herein illustrated and described, various process variables are possible of accommodation with the concentrator-washer 11. Thus, for a particular concentrate, substantial amounts of fresh wash fluid may be injected at a single initial or intermediate point in the washing region 38 through an injection port 40. The concentrate at that point may have achieved its desired degree of dryness, so that both the wash fluid added and the undesired materials, e.g., salts, dissolved and/or diluted by that fluid are removed from the washing region 38 through filter elements 30 in several downstream stages 36 of the washing region 36, thereby wringing-out and, in effect, redrying the rewetted concentrate. Alternatively, the concentrated slurry may be treated by injecting a limited amount of fresh wash liquid at a sequential plurality of injection ports 40 (FIG. 4) with the amount injected at any particular port 40 being essentially wrung out of the concentrate and drained from the washing region 38 along with any undesired materials picked up by it prior to arrival of the concentrate in way of the next wash fluid inlet port 40. Thus the washing operation of this procedure comprises alternating steps of limited rewetting and restoration drying.

In another functional mode or arrangement a limited amount of fresh wash fluid may be injected close to the concentrate discharge end of the washing region 38 through injection port 40A (FIG. 4) where the concentrated slurry has achieved its approximate degree of desired dryness. That fluid is then removed through the filter element 30B in the stage 36 downstream of the injection port 40A, and the now-contaminated wash fluid is injected next into earlier stage 36, that is, one upstream from the initial injection point. This process of injection, removal and re-injection may be continued with the wash fluid being counter-flowed through the concentrator-washer 11 and becoming increasingly contaminated as it is moved upstream.

To illustrate further the adaptability of the described apparatus to various types of feed material, consideration may be given to the situation of solids-containing fluid supplied to the concentrator-washer 11 having a concentration of solids in excess of 50%, with that material lacking adequate fluidity to be processed in a rotary concentrator-washer without the use of excessive power. In such a situation wash fluid may be added to an initial stage 36 of the apparatus to increase the fluidity of the feed material and at the same time wash impurities from it. If the concentration of the material initially fed to

the concentrator-washer 11 be, on the other hand, less than 50% solids it may be desirable to concentrate that material further before undertaking to wash it to remove impurities.

Where the solids concentration of a feed material is in the relatively low range 1% to 20% it may be desirable not to add wash fluid until the concentration approaches 50% solids following substantial processing of the material in a concentrating region. In such a situation the gross amount of fluid impurities in the original feed material would be removed before the first washing stage but non-fluid impurities might remain and the latter could be removed in the washing region of the apparatus. If the rate of wash fluid addition in the washing region corresponds to the rate of filtrate withdrawal in and from the involved washing stage, the injected washing fluid may tend initially to reduce the concentration of solids in the material being processed, but the immediately subsequent removal at the same rate of contaminated wash fluid will tend in turn to maintain a constant level of concentration from one side of the involved washing stage to the other.

Just as it may be desirable not to inject wash fluid into the initial stages of the concentrating region but instead to pre-concentrate a feed slurry before beginning washing, it may be desirable not to inject wash fluid into one or more of the final stages of the concentrator-washer if it be desired to wring out or dry the concentrated slurry thoroughly, i.e., increase its solids concentration appreciably just prior to discharge of the concentrate from the unit.

Another operative condition of the described apparatus may call for injecting wash fluid at every other stage in the washing region rather than at every stage. In that circumstance different solvents or other wash fluids may be used for various stages so that a different impurity is dissolved or diluted from the concentrate at the respective stages. A related consideration is that while a single pump with suitable control valves may be used to supply wash fluid to all of the stages in the washing region at which injection of wash fluid is desired, a separate pump for each such stage would have the advantage that each pump would function as a fluid metering and control device for the wash fluid supplied to its respective stage and, by use of separate pumps, more than a single wash fluid may be used for the respective stages.

From the foregoing it is clear that the described apparatus provides a unitary or single unit concentrator-washer for continuously and dynamically separating a concentrated slurry and a filtrate from a solids-containing fluid and removing impurities

from the concentrate so formed. At various places herein the expressions "filter element" and "filtering surface" have been used in connection with the physical components and the operational conditions with the physical components and the operational conditions of the concentrator-washer disclosed. It is to be understood that those expressions have been used only for the sake of convenience and clarity to identify and described particular components of a compound machine. For purposes of this specification, including its claims, the expressions are to be considered generic; that is, "filter element" is to be considered to relate to a filtering device having a filtering surface, or to a filtering support surface for a filtering element having a filtering surface. Similarly, "filtering surface" is to be considered as relating to a separate material which is added to a filter support surface or filter element, or to a filtering surface which is an integral part of a filter support surface or filter element.

In the preceding description and for the several embodiments disclosed it is to be understood that various elements described as being stationary or moving in the illustrations given can be modified to be mobile or stationary, provided only that the inventive concepts embodied in the appended claims be carried out. Thus the filter elements may be made to rotate relative to the housing in certain arrangements while the interposed discs may be made stationary relative to the housing, the essential feature being relative rotation between the filter elements and the discs. Similarly, elements which are particularly illustrated and/or described as being solid or perforated may also be changed in design.

WHAT WE CLAIM IS:—

1. A dynamic concentrator-washer for separating a filtrate and a concentrated slurry from a solids-containing fluid and washing the concentrated slurry with a wash fluid prior to discharge of the concentrated slurry from the concentrator-washer, the concentrator-washer comprising:
 a housing defining an enclosure having a concentrating region and a washing region;
 a first inlet in said housing for the introduction into said enclosure of a pressurized solids-containing fluid;
 a least one first annular element mounted within said concentrating region and having at least one radially extending surface thereon in the flow path of solids-containing fluid introduced into said enclosure through said first inlet;
 a shaft mounted in said housing on the longitudinal axis of said housing and extending through said concentrating region and said washing region;

at least one first radially extending element mounted on said shaft within said concentrating region and having at least one radially extending surface thereon in the flow path of solids-containing fluid introduced into said enclosure through said first inlet, said radially extending surface of said first radially extending element extending radially outwardly of said longitudinal axis in substantially parallel, spaced apart relation to said radially extending surface of said first annular element towards an interior surface of said housing but terminating in spaced relation thereto sufficient for fluid flow therebetween;
 said first annular element or said first radially extending element being a first filter element and said radially extending surface thereof being a filter surface disposed to pass a filtrate therethrough into the interior of said first filter element from solids-containing fluid within said concentrating region;
 a first outlet in said housing, said first outlet being connected to the interior of said first filter element for discharging filtrate from said concentrating region and said first filter element and thereby providing a concentrated slurry of solids-containing fluid in said concentrating region;
 at least one second inlet in said housing, said second inlet communicating with said enclosure for the introduction into said enclosure of a wash fluid to provide a mix within said enclosure of the wash fluid and said concentrated slurry;
 at least one second annular element mounted within said washing region and having at least one radially extending surface thereon in the flow path of said mix of concentrated slurry and wash fluid;
 at least one second radially extending element mounted on said shaft within said washing region and having at least one radially extending surface thereon in the flow path of said mix of concentrated slurry and wash fluid, said radially extending surface of said second radially extending element extending radially outwardly of said longitudinal axis in substantially parallel, spaced apart relation to said radially extending surface of said second annular element towards an interior surface of said housing but terminating in spaced relation thereto sufficient for fluid flow therebetween;
 said second annular element or said second radially extending element being a second filter element and said radially extending surface thereof being a filter surface disposed to pass wash fluid from said mix of concentrated slurry and wash fluid therethrough into the interior of said second filter element;
 a second outlet in said housing, said second outlet being connected to the interior of said second filter element for discharging wash



from the concentrate so formed. At various places herein the expressions "filter element" and "filtering surface" have been used in connection with the physical components and the operational conditions with the physical components and the operational conditions of the concentrator-washer disclosed. It is to be understood that those expressions have been used only for the sake of convenience and clarity to identify and described particular components of a compound machine. For purposes of this specification, including its claims, the expressions are to be considered generic; that is, "filter element" is to be considered to relate to a filtering device having a filtering surface, or to a filtering support surface for a filtering element having a filtering surface. Similarly, "filtering surface" is to be considered as relating to a separate material which is added to a filter support surface or filter element, or to a filtering surface which is an integral part of a filter support surface or filter element.

In the preceding description and for the several embodiments disclosed it is to be understood that various elements described as being stationary or moving in the illustrations given can be modified to be mobile or stationary, provided only that the inventive concepts embodied in the appended claims be carried out. Thus the filter elements may be made to rotate relative to the housing in certain arrangements while the interposed discs may be made stationary relative to the housing, the essential feature being relative rotation between the filter elements and the discs. Similarly, elements which are particularly illustrated and/or described as being solid or perforated may also be changed in design.

WHAT WE CLAIM IS:—

1. A dynamic concentrator-washer for separating a filtrate and a concentrated slurry from a solids-containing fluid and washing the concentrated slurry with a wash fluid prior to discharge of the concentrated slurry from the concentrator-washer, the concentrator-washer comprising:
a housing defining an enclosure having a concentrating region and a washing region;
a first inlet in said housing for the introduction into said enclosure of a pressurized solids-containing fluid;
a least one first annular element mounted within said concentrating region and having at least one radially extending surface thereon in the flow path of solids-containing fluid introduced into said enclosure through said first inlet;
a shaft mounted in said housing on the longitudinal axis of said housing and extending through said concentrating region and said washing region;

at least one first radially extending element mounted on said shaft within said concentrating region and having at least one radially extending surface thereon in the flow path of solids-containing fluid introduced into said enclosure through said first inlet, said radially extending surface of said first radially extending element extending radially outwardly of said longitudinal axis in substantially parallel, spaced apart relation to said radially extending surface of said first annular element towards an interior surface of said housing but terminating in spaced relation thereto sufficient for fluid flow therebetween;

said first annular element or said first radially extending element being a first filter element and said radially extending surface thereof being a filter surface disposed to pass a filtrate therethrough into the interior of said first filter element from solids-containing fluid within said concentrating region; a first outlet in said housing, said first outlet being connected to the interior of said first filter element for discharging filtrate from said concentrating region and said first filter element and thereby providing a concentrated slurry of solids-containing fluid in said concentrating region;

at least one second inlet in said housing, said second inlet communicating with said enclosure for the introduction into said enclosure of a wash fluid to provide a mix within said enclosure of the wash fluid and said concentrated slurry;

at least one second annular element mounted within said washing region and having at least one radially extending surface thereon in the flow path of said mix of concentrated slurry and wash fluid;

at least one second radially extending element mounted on said shaft within said washing region and having at least one radially extending surface thereon in the flow path of said mix of concentrated slurry and wash fluid, said radially extending surface of said second radially extending element extending radially outwardly of said longitudinal axis in substantially parallel, spaced apart relation to said radially extending surface of said second annular element towards an interior surface of said housing but terminating in spaced relation thereto sufficient for fluid flow therebetween;

said second annular element or said second radially extending element being a second filter element and said radially extending surface thereof being a filter surface disposed to pass wash fluid from said mix of concentrated slurry and wash fluid therethrough into the interior of said second filter element;

a second outlet in said housing, said second outlet being connected to the interior of said second filter element for discharging wash

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fluid from said washing chamber and said second filter element and thereby providing a washed concentrated slurry in said washing region; and

5 a third outlet in said housing, said third outlet being in the flow path of said washed concentrated slurry to discharge said washed concentrated slurry from said housing; said concentrator-washer being capable of
10 having drive means coupled thereto for causing relative rotation between said shaft and with it said radially extending elements, and said annular elements.

2. A dynamic concentrator-washer according to claim 1 wherein said annular elements are said filter elements, and said shaft is mounted for rotation whereby in use said housing and with it said filter elements remain stationary, and said shaft and with it
20 said radially extending elements are rotated by a said drive means.

3. A dynamic concentrator-washer according to claim 2 wherein said housing includes a front wall adjacent to an end of said longitudinal axis and a rear wall adjacent to the opposite end thereof, said first inlet is formed in said front wall, said concentrating region extends from said front wall, said third outlet is formed in said wall, and said
30 washing region extends from said rear wall.

4. A dynamic concentrator-washer according to claim 3 comprising a plurality of said filter elements within said concentrating region, a plurality of said filter elements within said washing region, and a plurality of said radially extending elements in alternating relation with said filter elements in both said concentrating region and said washing region.

5. A dynamic concentrator-washer according to claim 3 wherein each said filter element has a pair of opposed said filter surfaces.

6. A dynamic concentrator-washer according to claim 2 wherein each said radially extending element has additionally on at least one side at least one blade projecting generally parallel to said longitudinal axis and laterally towards an adjacent said filter surface.
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7. A dynamic concentrator-washer according to claim 6 wherein each said radially extending element has at least one blade on each side, said blades being configured to impel flow of fluid within said housing radially outwardly along one side of the associated radially extending element and radially inwardly along the other side thereof.
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8. A dynamic concentrator-washer according to claim 2 further comprising means connected to said third outlet for controlling the discharge of said washed concentrated slurry from said third outlet.
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9. A dynamic concentrator-washer according to claim 2 wherein said shaft comprises

a concentrating-region-shaft-portion extending through said concentrating region and a separate washing-region-shaft-portion extending through said washing region, said shaft portions being capable of having separate drive means connected to them and different rotational speeds imposed upon them.

10. A dynamic concentrator-washer according to claim 2 wherein a further said filter element has a pair of opposed filter surfaces and separates said concentrating region from said washing region with one of said opposed filter surfaces facing said concentrating region and the other thereof facing said washing region.
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11. A dynamic concentrator-washer according to claim 2 further comprising at least one third inlet in said housing in addition to said second inlet for the introduction into said enclosure of wash fluid, and at least one fourth outlet in said housing in addition to said second outlet for discharging wash fluid from said washing region, said third inlet and said fourth outlet both being located in said housing between said second outlet and said third outlet.
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12. A dynamic concentrator-washer according to claim 2 wherein said first inlet in said housing is adjacent to one end thereof, and said third outlet is adjacent to said other end thereof; and comprising a plurality of said filter elements in serial, spaced apart relation within said enclosure, each said filter element having at least one filter surface for passing therethrough according to location of any particular filter element either (i) filtrate from a solids-containing fluid, (ii) wash fluid from an intermix of solids-containing fluid and wash fluids, or (iii) both filtrate from solids-containing fluid and wash fluid from an intermix of solids-containing fluid and wash fluid, while retaining a concentrate of solids either unwashed or washed.
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13. A dynamic concentrator-washer according to claim 12 further comprising (i) a third inlet in said housing located between said first and second inlets therein, and (ii) pumping means connected between said second outlet and said third inlet for pumping at least a portion of the discharge from said second outlet to said third inlet for re-introduction of that portion of said discharge into said enclosure at a location upstream from the location of original introduction of fresh wash fluid into said enclosure.
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14. A dynamic concentrator-washer according to claim 13 further comprising a plurality of means between said first and second inlets for reintroducing discharge into said enclosure at a plurality of locations between the location of the respective discharge and that of said first inlet.
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15. A dynamic process for continuously separating a concentrated slurry and
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a filtrate from a solids-containing fluid and washing undesired material from the concentrated slurry to provide a washed concentrated slurry, the process comprising the steps of:

5 introducing a solids-containing fluid under pressure into one end of an enclosed housing having said one end and another opposite end and containing (i) a plurality of serially arranged, spaced apart annular elements each having at least one radially extending surface disposed in a path wherealong fluid may flow through said housing from said one end to said other end thereof, and (ii)

10 a shaft means including a plurality of radially extending elements arranged serially between successive ones of said annular elements in substantially parallel, spaced apart relation to said radially extending surfaces thereof and terminating in spaced relation to an interior surface of said housing sufficient for fluid flow therebetween, each said radially extending element having at least one radially extending surface disposed in said path wherealong fluid may flow through said housing from said one end to said other end thereof, said annular elements or said radially extending elements being filter elements and said radially extending surfaces of said filter elements being filter surfaces, the interior of each said filter element being in fluid flow communication with the exterior of said housing;

15 flowing the solids-containing fluid past and against said filter surface of at least a first said filter element and thereby and thereat effecting a separation of filtrate from the solids-containing fluid and providing a concentrated slurry including some undesired material within said housing;

20 discharging the separated filtrate from the interior of said first filter element and said housing;

25 introducing wash fluid into said housing and intermixing the same therein with said concentrated slurry and included undesired material;

30 flowing the intermix of wash fluid, concentrated slurry and undesired material past and against said filter surface of at least a second filter element and thereby and thereat effecting a separation of wash fluid and undesired material from the concentrated slurry and providing a washed concentrated slurry within said housing;

35 discharging the separated wash fluid and undesired material from the interior of said second filter element and said housing;

40 discharging the washed concentrated slurry from said housing at said other end thereof; and

45 continuously effecting relative rotation between said shaft means and with it said radially extending elements, and said annular elements to impel a radial flow of both

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solids-containing fluid and the intermix of wash fluid, concentrated slurry and undesired material across said filter surfaces of said first and second filter elements respectively;

70 the process being such that slurry flows continuously from said one end to said opposite end of said housing through respective concentrating and washing regions in said housing, being concentrated and then washed as it flows progressively downstream.

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16. A dynamic process according to claim 15 wherein said annular elements are said filter elements, said housing and with it said filter elements remain stationary, and said shaft and with it said radially extending elements rotate.

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17. A dynamic process according to claim 16 wherein said radially extending elements of said shaft means which impel a radial flow of solids-containing fluid are rotated at one speed and the radially extending elements of said shaft means which impel a radial flow of said intermix of wash fluid, concentrated slurry and undesired material are rotated at another, different speed.

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18. A dynamic process according to claim 16 wherein (i) wash fluid is introduced into said housing at a plurality of locations along the length between said ends thereof and is intermixed therein with the concentrated slurry, and (ii) separated wash fluid and undesired material are discharged from said housing via respective said filter elements at a plurality of locations along its said length which alternate with said locations at which wash fluid is introduced.

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19. A dynamic process according to claim 18 wherein (i) fresh wash fluid is introduced into said housing only at the wash fluid introduction location closest to said other end thereof at which washed concentrated slurry is discharged from said housing, and (ii) at the next adjacent wash fluid introduction location there is introduced separated wash fluid and undesired material discharged from said housing at the wash fluid discharge location closest to said other end thereof at which washed concentrated slurry is discharged from said housing.

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20. A dynamic process according to claim 18 wherein the one of said plurality of locations at which wash fluid is introduced into said housing closest to said other end thereof at which washed concentrated slurry is discharged from said housing is spaced from said other end by at least two filter elements and the radially extending elements particularly associated therewith whereby a final intensified effect of separating fluid material from said concentrated slurry is achieved prior to discharge of that slurry from said housing.

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21. A dynamic concentrator-washer substantially as hereinbefore described with re-

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ference to Figure 1 of the accompanying drawings.

22. A dynamic concentrator-washer substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

23. A dynamic process substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

24. A dynamic process substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1979.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY,
from which copies may be obtained.