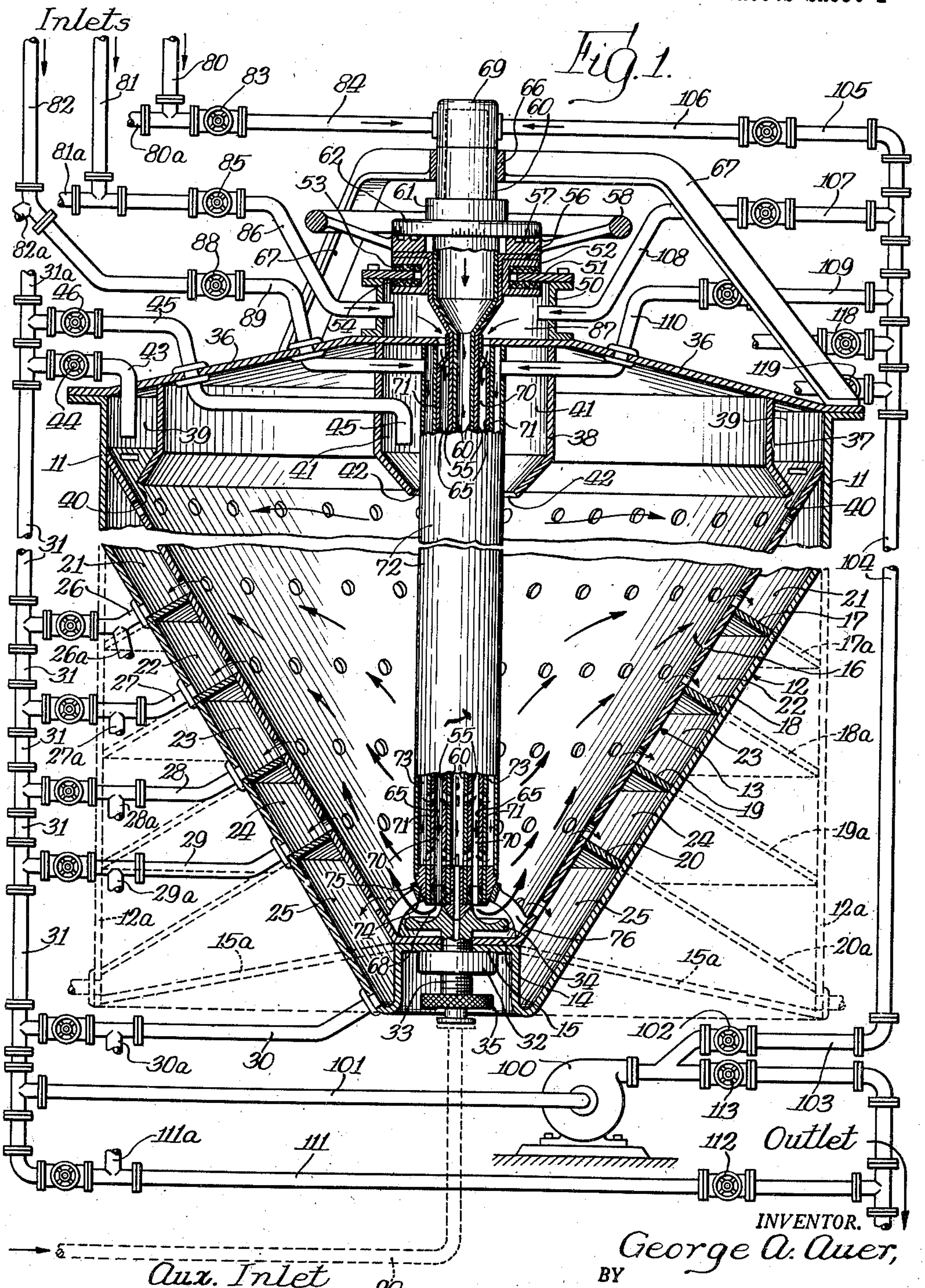
March 15, 1949. G. A. AUER 2,464,478

STREAMCURRENT APPARATUS FOR HANDLING MATERIALS

Filed June 6, 1945 2 Sheets-Sheet 1



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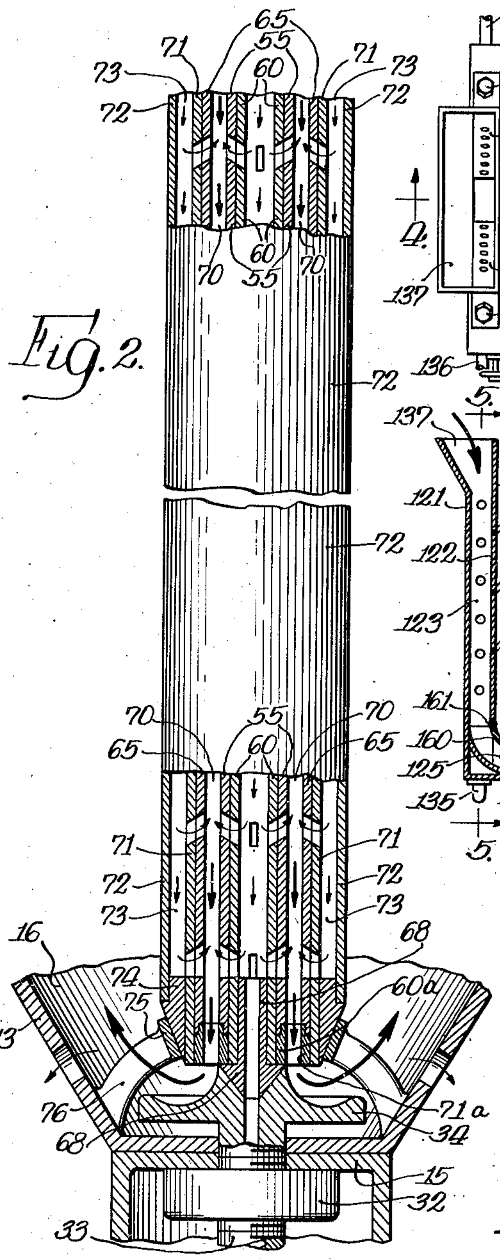

Fig. 2.

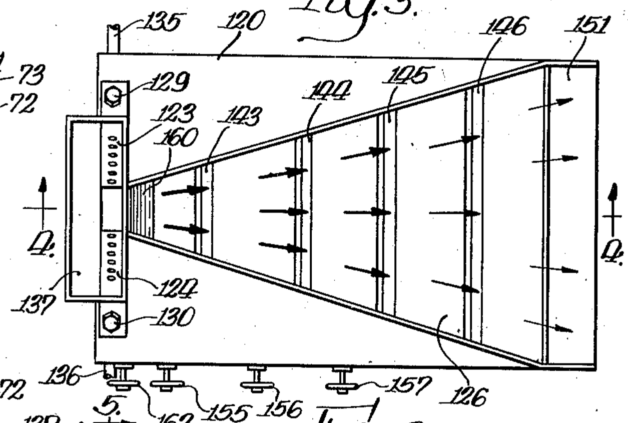

Fig. 3.

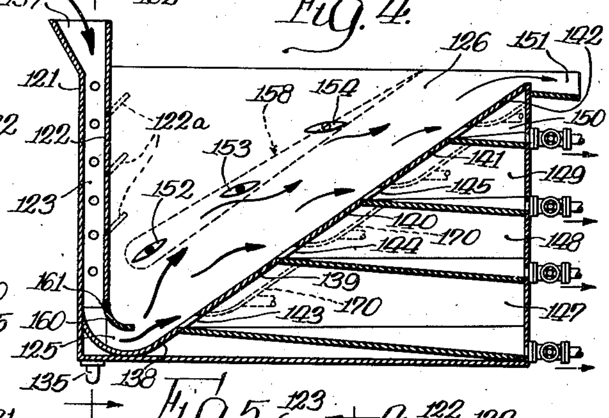

Fig. 4.

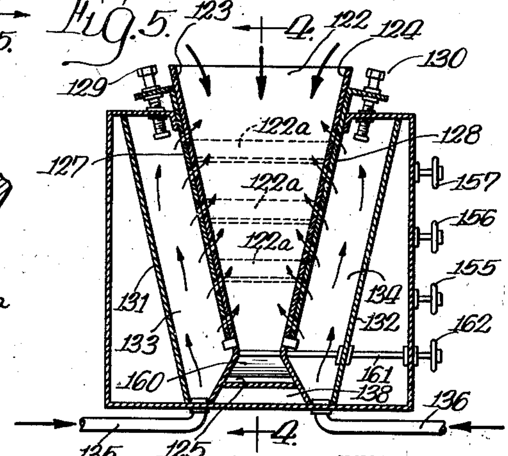

Fig. 5.

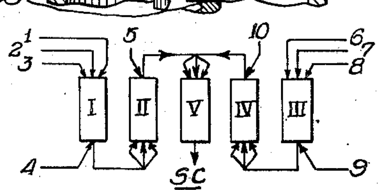

Fig. 6.

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Patented Mar. 15, 1949

2,464,478

UNITED STATES PATENT OFFICE

2,464,478

STREAMCURRENT APPARATUS FOR HANDLING MATERIALS

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Application June 6, 1945, Serial No. 597,839

35 Claims. (Cl. 259—95)

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This invention is concerned with streamcurrent apparatus for handling materials.

The term "handling" refers to operations such, for example, as noted in Patents Nos. 2,386,419 and 2,391,858, including mixing, blending, emulsifying, homogenizing, sustaining or maintaining of materials, and also refers to the separation of materials.

The terms "material" and "materials" are intended to mean substances, e. g., such as mentioned in the above noted patents, including gasolines, petroleum products, oils, numerous dispersions, solutions, liquids, emulsions, composite and artificial products; in the case of separating materials the terms are intended to include coal and ore particles which are to be concentrated or separated from a liquid separating medium in accordance with their specific gravities.

The term "streamcurrent" is defined in the above-mentioned patents. It refers to the control of a fluid or liquid body in motion for the purpose of producing controlled agitation in the presence of which fluid and solid particles will exhibit a substantially predictable behavior.

The new apparatus may be of the general type disclosed in the previously mentioned Patent No. 2,386,419, with improvements which enhance and extend its utility. It comprises a feed or injection device forming a plurality of feed or supply conduits and a first passageway or turbulence mixing chamber, a second passageway or streamcurrent chamber, means for feeding material into said first passageway for discharge directly and immediately into said streamcurrent chamber, and means for selectively and adjustably feeding material into said supply conduits for turbulent discharge into said first passageway, turbulent irrational intermixture therein and subsequent discharge therefrom into the streamcurrent chamber in which the turbulently and irrationally intermixed material is subjected to rational final intermixture in the presence of rational agitation. The rational agitation is controlled by flow-distributing means so constructed and arranged that the irrationally intermixed fluid material body is displaced symmetrically upwardly and laterally outwardly with upwardly diminishing magnitude and substantially without producing irrational turbulence. Valve controlled outflow ports are provided for selectively draining material from the fluid body in the streamcurrent chamber at vertically superposed levels thereof.

The second passageway may be properly termed a "streamcurrent separating chamber or compartment" when the apparatus is employed for separating materials rather than for mixing, blending or like purposes.

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The previously mentioned patents may be consulted for antecedents, general principles and theoretical considerations which apply in the present case.

Details will appear from the following description which is rendered with reference to the accompanying drawings showing some embodiments of the invention. In these drawings,

Fig. 1 is a diagrammatic sectional view of an apparatus made in accordance with the invention;

Fig. 2 shows, on an enlarged scale, part of the feed or injection device of the structure, Fig. 1;

Fig. 3 illustrates in diagrammatic top plan view another embodiment;

Fig. 4 represents a longitudinal section through the structure Fig. 3 along lines 4—4 thereof;

Fig. 5 shows a transverse section through the feed or injection device along lines 5—5 in Fig. 4; and

Fig. 6 is a diagram showing another embodiment of the invention.

The drawings are not to scale. The embodiments are shown in a schematic manner and the proportions of some parts are distorted at the expense of other parts so as to bring out details more clearly than would otherwise be possible.

The structure shown in Fig. 1 in full lines comprises a circular tank having a cylindrical upper section 11 and an inwardly and downwardly extending section 12. Within this tank is disposed a partition or flow-distributing wall 13 which is made in the shape of an inverted cone. This flow-distributing wall is provided with outflow ports at vertically superposed levels thereof. The bottom section 14 of the flow-distributing wall is joined with the bottom section 15 of the outer tank wall 12 and forms an inlet well for the introduction of the material which is to be subjected to treatment. The flow-distributing wall 13 forms the bottom or floor of the second passageway or streamcurrent chamber 16 of the machine.

Partitions 17—18—19—20 are provided, forming with the outer tank wall 12 discharge chambers 21—22—23—24—25. These chambers are provided with valved outlet conduits 26—27—28—29—30 terminating in the pipe 31. The wall 12 may be omitted, if desired, and the discharge chambers may be formed by suitable manifolds, one for each level of the fluid body in the streamcurrent chamber 16.

The recessed bottom 15 of the tank wall 12 is provided with a fitting 32 which is in fluid-tight connection with the tank and is internally threaded for the tubular threaded member 33. The latter extends upwardly into the tank and carries a head 34. As will be seen later on, this head operates as a flow control member and as a centering and supporting member for the feed and injection device formed by coaxial tubes extending downwardly into the tank. The tubular member 33 is operable from the outside by suitable means, for example, a hand-wheel or knob 35. Therefore, the supporting centering and flow control head 34 can be moved up and down within certain limits toward and away from the inlet well 14. In case of large structures which are sunk in the ground, the adjusting member 33 may be operated by remote control in any one of several known and approved ways. The member 34 may also be resiliently mounted; e. g., it may be upwardly biased by spring pressure so as to provide an elastic centering support for the feed and injection device. The arrangement which is to be used will very much depend on the size and purpose of the unit.

The machine is provided with a cover or lid 36 carrying a peripheral downwardly depending cylindrical baffle or insert partition 37 and a centrally disposed downwardly depending cylindrical baffle or insert partition 38. The insert 37 forms with the wall 11 of the tank a peripheral top chamber 39 which communicates with the passageway or streamcurrent chamber 16 through the annular space 40. The insert 38 forms with the centrally disposed downwardly extending feed and injection device a chamber 41 which communicates with the streamcurrent chamber 16 through the annular space 42. The inserts 37 and 38 are schematically shown as being attached to the cover only for the sake of convenience. They may be secured in any desired and suitable manner.

The peripheral top chamber 39 formed by the insert 37 is provided with a pipe 43 connected with the valve 44, and the latter communicates with the pipe 31. The chamber 41 is provided with a pipe 45 which communicates with the valve 46 and the latter also connects with the conduit 31. Several pipes such as 43 and 45 may be provided for the corresponding annular chambers 39 and 41 and may be suitably distributed at desired angular intervals in accordance with the size of the unit and the needs of the material to be handled. The annular inlets 40 and 42 may be arranged as shown, or either of these inlets may be extended downwardly or upwardly as desired. The pipes 43 and 45 serve the purpose of withdrawing material from the chambers 39 and 41, as may be desired or required, for any given condition. The pipe 45 is schematically shown as extending through the cover 36 across the annular space between the inserts 37 and 38 merely for convenience of description because all equipment is represented in the drawing in one radial plane. In a working structure, the pipe 45 may enter the chamber 41 from the top through the fitting 50. Pipes similar to those shown at 43, 45 connect with the valved inlets 118, 119, for re-injecting material into the chambers 39 and 41 for entrainment with the fluid material body within the chamber 16.

A float, as described in the previously noted Patent No. 2,386,419, may be provided for the control of a suitable vent valve to allow for the controlled escape of gases. Pressure and temperature control means may be provided if desired or necessary and wherever needed.

On top of the cover 36, centrally thereof, is disposed a tubular cross-sectionally U-shaped fitting 50. This fitting may support all the centrally disposed parts, including the feed and injection device and the insert 38, and may be mounted on the cover as a sub-unit. The fitting 50 carries an annular ring-like member 51 which extends radially inwardly and is disposed in an assembled cross-sectionally U-shaped journal 52. This journal is in rotatable engagement with the fixed ring-shaped member 51 through the medium of suitable glands or washers 53—54 which may be made of any suitable material. Roller bearings and any other suitable and approved journal structure may be substituted. The journal assembly is made fluid-tight and, if necessary, pressure-tight, in any desired and approved manner.

Attached to the assembled U-shaped journal 52 by means of the flange 56 is the downwardly depending pipe 55. The flange 56 is also attached to the hub 57 of an operating member shown in the form of a hand-wheel 58. Therefore, the hub 57 of the hand-wheel 58 is attached through the medium of the pipe flange 56 to the cross-sectionally U-shaped rotatable journal 52, and when the hand-wheel is rotated it will rotate the pipe 55 around the stationary centrally disposed pipe 60. The stationary pipe 60 and the pipe 55, which is rotatable around it, are shown to be of larger diameter on top. The sections of these pipes, which may be of different diameter, may be suitably assembled or joined. Keyed to the centrally disposed stationary pipe 60 above the hub of the hand-wheel is a member 61 having a flange 62 which maintains the journal assembly of the rotatably mounted pipe 55 by engagement with the hub 57 of the hand-wheel. The connection may be made fluid- and, if necessary, pressure-tight by means of a suitable labyrinth gland, including packed annular grooves, as diagrammatically indicated in the drawing. The flange 62 may be provided with suitable index marks coacting with index marks on the hub 57 of the hand-wheel 58 so as to indicate the angular displacement of the hand-wheel and therewith of the pipe 55 relative to the stationary pipe 60. The stationary pipe 60 constitutes a feed or supply conduit.

Suitably attached to the rotatable pipe 55 is a pipe 65 which extends downwardly concentric with the pipe 55, but spaced therefrom, the resulting annular space being indicated by numeral 70. Both the pipe 55 and the pipe 65 are thus rotatable by means of the hand-wheel. A hand-wheel is shown for the sake of convenience. In large structures the adjustment may be made by remote control in any desirable and suitable manner. The space 70 constitutes the first passageway of the structure. When supplied with material from the feed or supply conduit 60 and/or from the supply conduit 73, which will be presently described, it constitutes the turbulence mixing chamber of the machine.

Attached to the centrally disposed stationary pipe 60 near the top thereof is a casting or fitting 66 supported in a central position by legs or brackets 67. The latter are attached to the tank cover, as shown. On top of the pipe 60 is disposed an inlet fitting or casting 69, and connected with this fitting are the inlet pipes 84 and 106. Material to be treated may be injected into the feed or supply conduit 60 directly from the inlet 80 or may be injected thereinto for re-circulation through the pipe 106.

The pipe 60 extends downwardly within the rotatable pipe 55 and carries at its bottom a plug 68 which engages a recess in the flow control, centering and supporting head 34. The arrangement is particularly apparent from Fig. 2. Upward adjustment of the head 34 by means of the knob 35, or equivalent means, thus centers the pipe 60 at its lower end and also furnishes a support for the pipe. The pipe 60 carries at its lower end a suitable bearing 60a for rotatably journalling the lower end of the rotatable pipe 55. The rotatable pipe is thus likewise properly centered and supported. A simple friction type bearing 60a is indicated in the drawings. Any suitable bearing may, of course, be used.

The stationary centrally disposed feed and supply conduit formed by the pipe 60 and the rotatable companion pipe 55 are each provided with radially directed ports which may be upwardly inclined, as shown. The rotatable pipe 55 operates in the nature of a valve for adjusting the outflow from the pipe 60 through these ports into the first passageway or turbulence mixing chamber 70. The adjustment is made by means of the hand-wheel 58 or by equivalent means. Material can thus be injected into the passageway 70 in radially directed streams of adjustable magnitude or intensity entering the passageway in a plurality of levels. The number of ports in each level will depend on the size of the pipes 55 and 60. Leakage radially around the solid sectors of the conduit 60 in the various levels can be neglected in the practical operation of the structure. The arrangement comprising the stationary central feed pipe or supply conduit 60 and the rotatable valve pipe 55 is in certain respects similar to Patent No. 2,386,419.

Around the above described structure is disposed a stationary pipe 71 and an outer stationary pipe 72 forming an annular feed space or supply conduit 73. The pipes 71—72 are suitably attached at the top of the structure. They may be part of the cover 36 and depending therefrom, as shown, or they may form a separate sub-assembly, together with the other coaxial pipes as desired and as previously intimated. The pipes 71—72 depend downwardly concentric with the remaining pipes and are provided at the bottom with an annular ring-like member 74 which operates in the nature of a plug. The outer pipe assembly forming the annular feed space or supply conduit 73 is centered at the bottom by a ring-like member 75 which is supported on suitable legs 76. Numeral 71a (Fig. 2) indicates a suitable bearing carried by the pipe 71 at its lower end for rotatably journalling the lower end of the rotatable pipe 65. The bottom end of the feed and injection or inlet device comprising the various coaxial pipes is shown of cross-sectionally angular configuration. It may, of course, be suitably rounded in order to assist the hydraulic displacement of the fluid mass in the chamber 16 in accordance with the flow lines.

The stationary pipe 71 and the rotatable pipe 65 coacting therewith are both provided with upwardly inclined ports which may be brought into alignment by proper angular adjustment of the rotatable pipe 65 in a similar manner as the ports in the central pipe 60 may be brought into alignment with the ports in the rotatable coacting valve pipe 55.

Suitable spider washers may be provided at vertically spaced intervals, within the passageway 70 formed by the rotatable valve pipes 55 and 65, so as to maintain these pipes properly spaced and centered. Such washers are, of course, perforated in order to permit the flow of material through the passageway 70.

Assuming now that material is injected into either or both of the feed or supply conduits 73 and 60, such material will flow radially inwardly into the first passageway or mixing chamber 70. In other words, the material is emitted from the supply conduits 60 and 73 inwardly, in opposing adjustable jets, into the passageway or mixing chamber 70 which separates the rotatable valve pipes 55 and 65. The radial injection effects turbulence by collision and thus irrational intimate intermixture of the materials. The intensity or force of the jets is adjustable by the valve pipes 55 and 65 and by pressure injection of the materials. A stream of material may also be injected directly into the passageway 70 for intermixture with the materials injected thereinto from the conduits 60 and 73.

Three inlets 80, 81, 82 are shown at the top of the structure. These inlets may be connected with separate material holders or may feed material from one and the same source, e. g., a tank which receives the initial material components for subsequent intermixture and blending in the machine shown in Fig. 1. The inlet 80 connects over a valve 83 with the pipe 84, terminating in the fitting 69 which is joined with the pipe 60. Material can thus be adjustably injected through the inlet 80 into the centrally disposed stationary feed pipe or supply conduit 60. The inlet 81 connects over a valve 85 with pipe 86 terminating in the space 87 formed by the cross-sectionally U-shaped fitting 50 which communicates with the passageway 70. Material can thus be adjustably injected through the illustrated communicating openings into the first passageway or mixing chamber 70. Inlet conduit 82 connects over a valve 88 with pipe 89 for adjustably feeding material into the supply conduit 73 formed by the stationary pipes 71 and 72. Pipes 106, 108, 110 terminate similarly as pipes 84, 86, 89. They are provided for the purpose of re-circulating material from pipe 104 into the feed and supply conduits 60, 73 and into the passageway or mixing chamber 70, respectively. The inlets 80, 81, 82 also connect with the pipe 31 by way of valved connecting pipes diagrammatically indicated at 80a, 81a, 82a and 31a. These latter connections are provided for by-pass feeding of material from the inlets 80, 81, 82 by way of pipe 31 either to the outlet or by way of pipe 101 and pump 100, for injection through the pipes 106, 108, 110, into the feed and injection device as described.

An auxiliary inlet conduit is indicated in dotted lines 90 at the bottom of the figure, for feeding material, if desired, into the feed or supply conduit 60 through the boring in the supporting and centering head 34 and thence through the boring in the plug 68.

The partition or flow-distributing wall 13 is provided with ports of upwardly increasing outflow capacity for draining material from the second passageway or streamcurrent chamber 16 into the discharge chambers or cells 21—25. The material drained from the chamber 16 through these outlet ports collects in the cells 21—25 for selective withdrawal through the valved pipes 26—30, inclusive. These pipes are, of course, attached to the corresponding cells in such a manner that complete drainage can be effected. Valved branch pipes 26a—30a connect with the pipe branch 111a provided in pipe 111. These latter connections permit controlled withdrawal of material from the various cells directly to the outlet of the unit. Similar branch connections may be provided for the pipes 43, 45.

The additional equipment shown in the drawing comprising various valves and a pump is best described in connection with the operation of the structure.

The nature of the material or materials to be mixed, homogenized, emulsified or blended, or to be sustained and maintained, is known. The inlet capacity of the various conduits, that is, the magnitude of the inflowing streams of a given material through such conduits, under given feed conditions, is likewise known. The valve provisions, namely, the valves 55 and 65 coacting with the ports in the supply conduits 60 and 73, respectively, are suitably adjusted to the properties of the material to be handled and to the inflow thereof as well as in accordance with the results that are to be obtained. Several conditions are possible.

The valves 55 and 65 may be adjusted so as to block the radial outflow ports of the supply conduits 60 and 73, respectively. Material may be injected through the inlet 81 for downflow through the first passageway 70 and outflow directly into the second passageway or mixing chamber 16. The feed and injection device has in this case merely the function of an inlet and the material, e. g., a liquid, is subjected within the second passageway or chamber 16 to streamcurrent agitation which proceeds within the chamber 16 symmetrically upwardly and laterally outwardly with upwardly diminishing magnitude. The liquid leaves the streamcurrent chamber 16 through the outflow ports in the flow-distributing wall 13 in upwardly increasing amounts. A similar condition may also be produced in the structure shown in Patent No. 2,386,419.

It should be observed, however, that the present structure permits a controlled selectively adjustable withdrawal individually from the various levels of the fluid body in the streamcurrent chamber 16. Accordingly, the nature of the upflow in this chamber and streamcurrent agitation or displacement resulting therefrom is adjustable. Adjustment may be such as to block the outflow from all but the top level of the flow-distributing wall 13. All the material emitted from the feed and injection device will thus be forced to travel to the top. Alternatively, the outflow from all but the bottom level may be blocked. The result will be bulk turbulence within the chamber 16. Adjustment may be provided for differential withdrawal from the various levels of the mixing chamber, or for symmetric upwardly adjustably increasing withdrawal, so as to produce true streamcurrent conditions substantially without causing irrational turbulence in the fluid body within the chamber 16.

The valves 55 and 65 may also be adjusted for a desired radial outflow into the first passageway or mixing chamber 70, but material may be fed only from the inlet 80 into the supply conduit 60. The material in this case drops downwardly within the supply conduit 60 and flows in jets of desired intensity, according to the feed pressure and adjustment of the ports, radially outwardly into the first passageway or mixing chamber 70. The liquid then flows downwardly within the chamber 70 and out into the streamcurrent chamber 16 exactly as in the first case, with the difference that, while the liquid passes from the supply conduit 60 into the mixing chamber 70, it is subjected to more or less intense turbulent agitation.

A similar operation results from adjustment of the valve tubes 55 and 65 as in the case just mentioned, but feeding material only through the inlet conduit 82 into the supply conduit 73. The material is in this case ejected radially inwardly through the ports in the pipe 71 in streams or jets of adjusted intensity according to the setting of the valve 65, thus subjecting it to agitation and turbulence within the first passageway or mixing chamber 70, and flows downwardly and out of this chamber into the second passageway or streamcurrent chamber 16 wherein the agitation is of a controlled nature as previously described, which may proceed symmetrically upwardly with upwardly diminishing magnitude as particularly disclosed in detail in Patent No. 2,386,419.

The auxiliary inlet 90 may or may not be provided, but if it is provided it may be used for injecting liquid from below into the central supply conduit 60 for intermixture with liquid injected into this conduit from the inlet 80 or for intermixture with liquid injected into the first passageway or mixing chamber 70 from the supply conduit 73.

There are thus numerous adjustment possibilities and therefore possibilities for subjecting to treatment materials requiring agitation which may range from imperceptibly mild displacement to intense and even violent turbulence involving pressure and shearing forces. The material fed into the machine may be a composite liquid coming from several sources, for example, several oils or gasolines that have to be mixed. Alternatively, the material may be a suspension, dispersion or solution requiring blending or maintaining of homogeneity. Emulsions may be prepared by injecting desirable components into the first passageway or mixing chamber 70 and into the conduits 60 and 73, respectively, for turbulent intermixture within the passageway 70. Materials may be homogenized in like manner. Desirable degrees of turbulence may be produced. The injection and feed device may be provided with suitable heating or cooling jackets, if desired.

Assuming, for example, that it is desired to intermix four different grades of gasolines or oils, these four grades may be drained from separate holders through the inlets 80, 81, 82 and 90, respectively. The valves 83, 85, 88 connecting with the conduits 84, 86, 89 are suitably adjusted. There is, of course, a valve provided in the conduit 90. The valve pipes 55 and 65 are properly adjusted in accordance with the intensity of turbulent agitation that is desired, and the various solutions or liquids are then simultaneously injected in desired amounts and with desired pressures. The result is more or less intense desired turbulent agitation within the first passageway or mixing chamber 70 by collision of the numerous jets or streams of liquid emitted from the supply conduits 60 and 73 with the material flowing through the chamber 70. The turbulent product leaving the feed and injection column is discharged downwardly into the second passageway or streamcurrent chamber 16 and is there subjected to the rational upward and outward displacement to effect the final intermixing, homogenizing or blending of the materials. The more or less high state of agitation or ebullition of the turbulent material is gradually reduced as the liquid rises in the streamcurrent chamber 16. The flow in the chamber 16 may be so adjusted that the upper strata of the liquid within this chamber are substantially quiescent.

The above described operations may be carried out as described or by the use of the pump 100. Valves 83, 85, 88 are for this purpose closed and inlets 80, 81, 82 are connected with the pump by way of pipes 31 and 101. A valved branch conduit from pipe 90 to the pump may be provided for adding the component conducted through this pipe. The pump propels all the components to be mixed, coming from pipes 31, 90 and 101, through the valve 102, pipes 103, 104, into the valved pipes 105—106, 107—108, 109—110, thus effecting a certain degree of intermixing incident to the flow through the feed conduits 31, 101, to and through the pump and thence to and through the conduits 103 and 104. The mass is then divided again and is fed in adjusted amounts into the passageway 70 and into the supply conduits 60 and 73, respectively, for turbulent intermixture within the passageway 70 and discharge into the chamber 16, as described. The fluid from pipe 90 may, of course, be injected directly instead of by the pump 100.

The blending, mixing, homogenizing, emulsifying, dispersing or other handling of some materials may require recirculation or turnover pumping which may be carried out by use of the pump 100. Adjusted amounts of material may be drained selectively separately from any of the chambers 39, 41 and 21—25, and may be fed to the pump by way of conduits 31 and 101 and may then be returned to the feed and injection device by way of valve 102 and conduits 103—104 for reinjection selectively through any one or all of the inlets 106, 108, 110. For example, it is possible to withdraw material from one or more selected levels or chambers of the device and return it by way of pipes 105—106 to the supply conduit 60; or the material may be returned to the first passageway or mixing chamber 70 by way of pipes 107—108; the material may also be returned to the supply conduit 73 by way of pipes 109—110; and, finally, material may also be returned to the top chambers 39, 41 by way of valved conduits 118, 119. Just which of the various possibilities for turnover pumping is to be used, alone or in combination with others, will be determined by conditions arising in practice. Some materials may require turnover pumping and reinjection through all channels simultaneously so as to obtain repeated treatment with maximum intensity and entraining agitation. Other materials may require only recirculation through the second passageway or streamcurrent chamber 16 by way of the first passageway 70 mainly for the purpose of gradually killing ebullition

Adjusted amounts of material may be drained selectively individually from either or both of the chambers 39, 41 and from any one or all of the discharge chambers 21—25 for discharge through the conduit 111, by way of valve 112 to the outlet. The withdrawal of material may also be forced selectively from any one or all of these chambers or cells by the pump through the valve 113 to the outlet. The amount of material to be drained from each chamber may be determined in either case by proper valve setting. Draining of material for discharge from some of the chambers or cells and turnover pumping of material from other chambers or cells may be obtained by suitable valve settings. Turnover pumping from selected levels of the fluid material body in the streamcurrent chamber 16, together with controlled discharge from some or all of the levels may be practiced simultaneously with feeding fresh liquid into the tank or after the tank is completely filled with liquid. All these and other possibilities are believed to be sufficiently obvious from the drawing Fig. 1.

Materials may be treated with gases, if desired. For example, it may be required, in connection with certain emulsions or mixtures, to subject a material to turbulent agitation in the presence of air or other gas. The material may be fed through the first passageway 70 and the gas may be introduced through either or both of the supply conduits 60, 73. Any other suitable and desirable feed procedure may be adopted within the possibilities of the machine. The gas, in such case, takes the place of a material component of the final product.

It should be observed that the structure can be drained completely, leaving only the film of material that will inevitably adhere to the tank walls. The streamcurrent agitation as described is operative and affects the entire material in the chamber 16 regardless of the amount of material which may be reposing in the chamber at any time.

The structure is also adapted to serve as a storage tank for suspensions, dispersions, emulsions, solutions, blended liquids, and other materials which display a tendency to separate or deteriorate when subjected to quiescent conditions. The required agitation is furnished purely as a by-product of the injection and/or withdrawal of material without any mechanical agitating means. Turnover circulation may be employed periodically, in case of storage, during prolonged intervals of inactivity, that is, when no material is normally added or withdrawn for use.

The new structure facilitates and accelerates the handling of materials for numerous purposes, as compared with the operation of prior devices, cutting down the cost of operation, and renders the operations more certain and more effective. There are no moving parts or machinery that may get out of adjustment and cause expensive repairs or replacements. The initial cost of the apparatus will in most cases be less than the cost of orthodox equipment, and maintenance costs will also be reduced.

Any desired condition of turbulence, agitation and hydraulic displacement may be produced substantially with calculable certainty, because all factors required for calculating magnitude of pressure, turbulence forces and displacement of the material at any point within the structure are known and can be adjusted at will to accommodate any given set of requirements. Desired temperature conditions may likewise be produced at any section of the structure by the provision of suitable heating or cooling means.

The outer tank 12 may be made cylindrical, as indicated in dotted lines marked by the numeral *12a*. The outer tank spaces, that is to say, the collecting cells or discharge chambers such as 21—25, inclusive, will then, of course, be enlarged, as indicated by dotted lines *17a*—*20a* showing the required partitions corresponding to partitions 17—20. The structure is in such a case provided with an upwardly sloping tank bottom *15a* which is joined with the bottom 14 of the flow control wall 13, as shown. The outlet conduits connecting with the pipe 31 are suitably provided in accordance with the structure shown in the drawing and analogous thereto. The outlet conduits again are placed so as to effect complete drainage from the various cells and chambers of the tank.

The structure may be made square or polygonal, if desired. The flow control wall 13 would, of course, follow the general shape of the outer tank; e. g., it would be made in the form of an inverted pyramid. The feed and injection device can also be made cross-sectionally square or polygonal instead of being composed of cross-sectionally circular tubes. Sliding valves would in such case be used in place of the rotatable valves 55—65. The use of sliding valves in place of the rotatable valves is generally feasible also in the illustrated structure. The tubes 55—65 may, for example, be mounted for vertical sliding displacement by suitable lever or cam control or by screw control generally as shown for the adjustment of the valve members 127—128 illustrated in Fig. 5.

The embodiment diagrammatically shown in Figs. 3, 4 and 5 comprises a feed and injection device which is disposed at one end of a generally rectangular tank structure 120. The device includes the end walls 121—122 and the perforated strip-like side walls or inserts 123—124 forming the first passageway or turbulence mixing chamber which tapers in downward direction and terminates in an opening 125 for direct and immediate discharge of material in turbulent condition into the second passageway or streamcurrent chamber 126. In back of the side walls 123—124 are disposed valve members 127—128, respectively, which may be adjusted by suitable means, e. g., screws 129—130, respectively. These valve members are perforated just like the side walls 123—124 and the perforations may be adjusted for desired outflow of material into the first passageway or mixing chamber. The perforations in the side walls or strips 123—124 may be provided with spray nozzles, if desired. The valve members are slidably secured by means of suitable guides. One of such guides is indicated at the bottom of each valve member. Insert partitions 131—132 form walls of chambers 133—134 which constitute the supply conduits of the structure. The supply conduit 133 receives material from the inlet 135 and the supply conduit 134 receives material from the inlet 136. The first passageway or turbulence mixing chamber receives material from the inlet 137 shown in the form of a hopper.

The second passageway or streamcurrent chamber comprises a floor or bottom formed by the sections 138—139—140—141—142, constituting a flow control or flow-distributing wall corresponding to the perforated insert 13 in the previous embodiment. Numerals 143—144—145—146 indicate ports for the outflow of material from the chamber 126 at vertically superposed levels, corresponding to the outflow ports in the flow-distributing wall of the first embodiment. Each port discharges into a separate collecting or discharge chamber or cell. Thus, the port 143 discharges into the cell 147; the port 144 discharges into cell 148; port 145 discharges into cell 149; and port 146 discharges into cell 150. Each cell is provided with a valved outlet, as particularly shown in Fig. 4. Numeral 151 indicates an overflow.

A suitable gate or valve, e. g., a slide gate, may be provided directly at each of the ports 143—146 instead of or in addition to the valves in the outlets from the cells receiving material from these ports. It should be noted that the bottom of each of the cells 147—150 is dished so as to provide for complete drainage.

Additional flow control or flow-distributing baffle members 152—153—154 are shown in Fig. 4. These members are omitted in the schematic drawing, Fig. 3. Each of these members is made in the form of a preferably streamlined bar or strip rotatably mounted on a suitable shaft and extending transversely across the chamber 126 above the floor thereof. The shafts project to the outside and are adjustable by suitable means, for example, hand-wheels. Hand-wheel 155 is provided for angular adjustment of the flow control member 152; hand-wheel 156, for angular adjustment of the flow control member 153; and hand-wheel 157, for angular adjustment of the flow control member 154. Additional such flow control members may be provided if desired or necessary.

A flow control partition indicated in dotted lines 158 may be provided in place of the flow control members 152—154, or in addition thereto and disposed thereabove. This partition, if used, forms a roof over the flow-distributing bottom wall, and the upwardly inclined space defined thereby constitutes the streamcurrent chamber. The partition also forms the floor of an additional chamber which extends thereabove and which may be used as an additional turbulence mixing chamber adapted to discharge material into the streamcurrent chamber 126.

The first passageway or mixing chamber of the feed or injection device empties into the second passageway or streamcurrent chamber by way of the opening 125 which is controlled by a gate or valve 160. This valve is operable by a shaft 161 which is adjustable by means of a hand-wheel such, for example, as indicated at 162.

Gates or valves shown in dotted lines at 122*a* may be provided in the end wall 122 of the first passageway or mixing chamber for discharge of material from selected levels of this passageway into the streamcurrent chamber. These valves may be mounted just like the valve 160 and operated by suitable levers or hand-wheels, or may be sliding valves and operated either from the side or from the top of the structure.

The operation of the apparatus shown in Figs. 3–5 may be substantially exactly like the operation described in connection with the structure Figs. 1 and 2, except that the first and second passageways or mixing chambers of the machine illustrated in Figs. 3–5 are open at the top and are operated under atmospheric pressure, whereas the corresponding passageways of the machine shown in the previously discussed drawings are closed to the atmosphere.

An operation cycle may be briefly described, assuming that it is desired to blend three different kinds of materials to form a desired mixture. One of the components is injected into the hopper 137 for downflow through the first passageway or turbulence mixing chamber. The material flows downwardly through the chute-like passageway toward the opening 125 and into the second passageway or streamcurrent chamber in accordance with the setting of the valve or gate 160. Other components may be injected through the conduits 135—136, respectively, for upflow in the feed or supply conduits 133—134. These components then flow through the ports in the valve members 127—128 and through the ports and, if desired, through nozzlers in the associated inserts or side walls 123—124, in the direction of the arrows shown in Fig. 5, for intermixture with the downwardly flowing material coming from above. Turbulence is produced by this action and agglomerates are broken up and agglomeration is prevented. The intensity of the jets, sprays or streams injected into the first passageway or mixing chamber through the openings in its side walls may be regulated by the pressure with which the material is injected through the inlets 135—136 and by properly setting the valve members 127, 128, to adjust the size of the ports as desired. Adjustable inlet ports corresponding to the ports in the walls 123—124 may also be provided in the end walls 121—122 of the passageway.

The turbulently intermixed material flows through the properly adjusted inlet gate opening 125 into the stream current chamber of the apparatus, and then flows from the inlet opening or inlet well upwardly and laterally outwardly in the general direction of the arrows shown in Figs. 3 and 4. The flow in the upper strata of the fluid material body is controlled by the flow control and flow-distributing members such as 152—153—154, or by the partition 158, respectively.

Material is adjustably drained into the outflow cells or discharge chambers 147—150 at vertically successive levels of the fluid body forming in the streamcurrent chamber.

The operation of the embodiment shown in Figs. 3–5 is thus generally similar and, in its broad aspects, identical with the operation of the embodiment previously described with reference to Figs. 1 and 2.

Pipe and valve connections may be provided in conjunction with the apparatus Figs. 3–5 generally analogous to the pipe and valve means shown in Fig. 1. It is understood, of course, that the machine shown in Figs. 3–5 may be made fluid- and pressure-tight and operated just like the first described embodiment simply by providing suitable covers for the two serially related passageways or mixing chambers, and connecting the necessary conduits thereto.

The embodiment shown in Figs. 3–5, when compared with the embodiment shown in Fig. 1 indicates the versatility and adaptability of the invention to structural modifications. The functional adaptability, that is to say, the possibility to use the invention in a great number of basic operations such as mixing, blending, etc., etc., has already been discussed. It will now be shown that the invention may also be usefully applied in the separation of materials.

This statement may at first seem surprising because the concept of separating would seem to be in conflict with the idea of sustaining a mixture such, for example, as a coal-oil suspension. There is, however, nothing incompatible about the two concepts because they have basic common features. At the basis of each is the concept of "mixing." Before a suspension can be sustained it must be mixed, that is, the solids must be uniformly dispersed or distributed in the liquid phase; and before a separation of solid particles in accordance with their specific gravities can be accomplished in a fluid separating medium, such particles must be intermixed with the medium, i. e., they must be distributed or dispersed in the medium. Therefore, a separator, for example, a hydraulic separator, may be considered in the light of a mixer.

The separation will be successful in the measure in which uniform dispersion or distribution of any given particles can be accomplished in a fluid medium. The present invention is adapted to furnish uniform distribution of solids in a liquid, and this feature may therefore be applied in the solution of the problem of dispersing solids in a liquid preparatory to or incident to separation from the liquid.

In maintaining or sustaining a product such, for example, as a coal-oil suspension, the problem is one of sustaining a liquid containing in dispersion solid particles of substantially uniform size and uniform specific gravity. If we consider separation, we are confronted with a different problem, namely, separating from the liquid medium solid particles of different sizes and/or specific gravities.

The separation of such particles will be successful in the measure in which organized statification can be accomplished. It will be clear that the turbulence of the liquid separating medium has a vital bearing on the subject. Organized statification is impossible in the presence of irrational unpredictable turbulence, and such turbulence is in conflict with and impedes stratification and therefore separation.

The new structure is adapted to displace a liquid body hydraulically with upwardly diminishing magnitude and substantially without creating irrational turbulence. This feature may be utilized for separation. In the presence of such hydraulic displacement heavy particles will obviously tend to organize near the bottom, and light particles will float toward the top.

It will thus be seen that the basic theoretical requirements for separation of materials are identical with those for mixing and sustaining or maintaining or blending of suspensions. Certain features of an apparatus adapted to satisfy the latter can therefore be sensibly adopted to meet the former.

Keeping the above remarks in mind, it will be easy to understand the operation of the machine shown in Figs. 3–5 when used as a separator.

It may be assumed, for example, that coal of a certain specific gravity, say 1.35, is to be separated from heavier impurities and that the size of the largest particles is less than ½″, e. g., that the particle size of the raw feed is ¼″ x 0″ or even smaller.

The raw feed is introduced into the hopper 137 and drops downwardly in the first passageway or turbulence mixing chamber. An agitating medium, which may be air of water or both, is introduced through the inlets 135—136 for upflow in the supply conduits 133—134 and outflow in jets, streams or sprays into the passageway in the path of the downflowing raw feed. Turbulent mixing agitation of a desired intensity is thus produced in the first passageway or mixing chamber as described before, to break up agglomerates, to prevent agglomeration, and to produce thorough intermixing and dispersing of the solid particles in the liquid.

Previously known separators, generally and broadly speaking, do the same thing as described in the preceding paragraph. The raw feed is dropped into a tank containing a liquid medium and liquid currents or air currents (which may be employed in the present structure) are injected into the body of the liquid medium producing turbulence and hydraulic displacement. Agitation is, in addition, produced by mechanical means, e. g., rotating paddles, propellers or the like.

As pointed out in the previously mentioned patents co-pending and as noted before, such agitation causes irrational and unpredictable turbulence, producing drawbacks which impede proper uniform distribution or dispersal of the solids in a liquid. The requirement of producing uniform dispersion of the particles in the liquid separating medium is thus violated.

Also, as mentioned before, irrational turbulence conflicts with the separation of the particles from the liquid because it impedes the organized stratification of the particles. The industry is in this respect in a dilemma. Agitation must be applied to disperse and to distribute the particles, and the degree of agitation that would be desirable to obtain uniform distribution causes such turbulence that stratification and cleancut separation are made impossible. The detriment becomes particularly manifest when it is attempted to separate solids of relatively small particle size. There is no hydraulic separator known at the present time which is adapted to produce entirely satisfactory separation, e. g., of coal of a particle size ranging from less than ½" to 0" and especially small size material ranging from ¼" to 0" or smaller. The invention is intended to contribute toward remedying this shortcoming.

One of the characteristic features which distinguishes the present invention, when used for the separation of materials, from the prior art, resides in dispersing and substantially uniformly distributing the solid particles in a fluid medium, by the application and use of irrational agitation, in a first passageway or mixing chamber, where irrational turbulence resulting therefrom cannot conflict with the separation, and carrying out the separation of the particles in accordance with the specific gravities thereof, by the application of controlled hydraulic displacement of the fluid body containing the particles thus dispersed therein, in a second passageway or separating chamber, upwardly and symmetrically laterally outwardly, with upwardly diminishing magnitude, to accomplish organized stratification and separation substantially in the absence of irrational turbulence. The prior art, in contradistinction, attempts to accomplish dispersion of the particles and separation thereof at the same time; that is, it attempts to accomplish separation in the presence of irrational and unpredictable turbulence.

The intermixed turbulent material leaves the first passageway or mixing chamber through the gate opening 125, and the fluid body, forming in the streamcurrent chamber is continuously rationally displaced symmetrically upwardly and with upwardly diminishing magnitude or intensity.

It will be clear that in the presence of such solely hydraulic displacement the solids in the liquid will stratify in accordance with their specific gravities and/or sizes, the heaviest or largest components remaining near the bottom and the lightest or smallest floating toward the top.

An inspection of the drawing, Fig. 4, will explain the behavior of the material. The intermixed turbulent mass consisting of the liquid separating medium and the solids dispersed therein leaves the feed and injection device in downward direction with a force which, in an open structure such as shown, will depend on the hydrostatic head therein, or rather to say, on the amount of liquid injected thereinto to supply the quantities of liquid withdrawn from the separating chamber.

Stratification is initiated within the first passageway or turbulence mixing chamber of the fed column by the hydraulic displacement caused by the action of the liquid currents issuing from the ports in the side walls as described. Assuming the valve or gate 160 to be suitably adjusted and the gates 122*a* closed, the mass of material is deflected at the bottom of the feed column in the direction of the prominent arrows. There is an upward component tending to lift the

material generally in the direction of the flow control member 152. The heaviest particles tend to remain near and at the bottom, moving toward the outflow port 143, and the lighter particles are lifted up. From then on the displacement of the mass continues, substantially without irrational turbulence, upwardly and laterally outwardly with upwardly diminishing intensity, along the flow-distributing wall or floor, sweeping toward the overflow 151. The organized stratification persists, the heavier particles moving along at and near the bottom of the stream and the progressively lighter particles at and near its top layer. Liquid containing particles of upwardly progressively lighter specific gravities may be removed through the ports 144—146. The lightest particles may be discharged at the overflow 151.

The organized stratification within the upwardly and outwardly moving stream may be assisted, if desired, by the injection of fluid or air currents sectionally, through the floor plates 138—142. These plates may be perforated for this purpose, and each may carry a hood at the bottom side, as indicated at 170, which is connected with a suitable fluid or air supply. The supply of fluid to the hoods may be uniform or may be in upwardly lessening amounts and/or pressure.

Irrational turbulence, which may become manifest in the form of eddies, is broken up by the flow control members such as 152—154 and/or by the flow control partition or roof 158, if such partition is employed. Eddies that may be produced above the control members have no detrimental effect on the controlled material flow along the floor of the structure.

It is understood, of course, that sufficient liquid must be added in the feed and injection device to maintain any desired flow of liquid through the separating chamber toward the overflow. Alternatively, make-up liquid may be added into the space above the partition 158, if such partition is used, for downflow and intermixture with the flow along the floor.

The streamcurrent motion of the material body is regulated and controlled by the shape of the separating chamber having the upwardly sloping floor and outwardly flaring side walls (see also Fig. 3) and by controlled withdrawal of material, i. e., liquid and solids contained therein, from the various levels of the separating chamber.

The gates 122*a* may be used for selectively admitting turbulent material into the separating chamber either in conjunction with the bottom opening 125 or with this opening closed by the valve 160.

The use of a flow control partition such as indicated at 158 presents additional operating and control possibilities. The partition forms the roof of the streamcurrent chamber 126 disposed underneath, and thus forms the floor of an auxiliary mixing chamber disposed thereabove. Turbulent material may be injected into this auxiliary chamber from the first passageway selectively through the gates 122*a* for downflow into the streamcurrent separating chamber 126 through the space between the wall 122 and the lower left end of the partition 158. This space may be controlled by a suitable valve. The material may thus be agitated and roughly separated in stages, first within the passageway receiving the raw feed from the chute 137, and second within the auxiliary chamber above the partition 158. Mechanical agitating means may be used in either or both stages, as desired. The material which is fed to the auxiliary chamber through the gates 122*a* is pre-selected by the rough separation or stratification which occurs in the first passageway. It will contain a preponderant amount of smaller and lighter particles, depending on the level from which it is drawn from the first passageway. Accordingly, the material discharged through the opening **125** will be mainly of heavy specific gravity, seeking the low discharge levels from the streamcurrent chamber **126**, and the material coming from the auxiliary chamber will be mainly light material which is added to the flow at a higher level and continues toward its upwardly disposed discharge points.

Re-circulation of a product withdrawn from one or more of the various levels of the streamcurrent chamber **126** may be practiced in accordance with explanations furnished in connection with the description of the apparatus shown in Figs. 1 and 2.

The liquid separating medium may be water, as described, or a suitable heavy density liquid, i. e., a liquid of a specific gravity heavier than water.

Each of the discharge chambers **147**—**150** may terminate in a housing, if desired, and each such chute may enclose a suitable mechanical conveyor for removing the material deposited therein. The housings may be disposed in vertically and transversely staggered relation at the discharge end of the machine.

The separation of materials has been discussed and explained particularly with reference to Figs. 3, 4 and 5. There is, of course, no inherent limitation that would stand in the way of using for the separation of materials the machine shown in Figs. 1 and 2. This applies particularly to the separation of finely divided materials.

The separation of coal has been described to give an example. The invention may be found useful in the separation of other relatively finely divided or comminuted materials and substances.

Referring now again to the subject of mixing, blending and like operations, the apparatus so far described, i. e., the machine shown in Figs. 1 and 2, permits the handling of four material components. This by no means exhausts the possibilities of the invention. The apparatus may be constructed so as to permit the intermixture of any number of components within the most complex practical requirements. For example, the apparatus may provide for the treatment of a plurality of material components in stages, as schematically indicated in Fig. 6 and as briefly described below.

A desired plurality of handling units, e. g., five units, numbered I–V, as shown in Fig. 6, may be disposed at one end of a rectangular tank structure such, for example, as described in connection with Figs. 3–5, taking the place of the feed and injection device of the previously discussed embodiment. The handling units I, II and III, IV may also be placed outside of a circular tank structure and the handling unit V may be disposed centrally of the tank as shown in Fig. 1. Unit V discharges in either case into the second passageway or streamcurrent chamber of the machine. Each of the units I–V may be constructed as described, for example, in connection with the feed and injection device of the machine shown in Figs. 1 and 2. Accordingly, each of these units I–V is adapted to handle three or, rather to say, four material components. Each of the units I, II, III, IV may be provided with a closure cap at its discharge end, for receiving the fluid mass intermixed therein, and for conducting such mass through suitable pipes and valves to the next stage.

In Fig. 6, the handling units I–V are interconnected in such a way as to intermix a plurality of material components in accordance with the formula

$$\text{(A)}\qquad \begin{array}{l} 1+2+3+4\rightarrow \mathrm{I}\rightarrow +\ 5\rightarrow \mathrm{II}\rightarrow \mathrm{V}\rightarrow SC\\ 6+7+8+9\rightarrow \mathrm{III}\rightarrow +10\rightarrow \mathrm{IV}\rightarrow \mathrm{V}\rightarrow SC \end{array}$$

wherein the Arabic numerals indicate the material components and the Roman numerals indicate the corresponding handling units. It will be seen that material components **1**, **2**, **3** and **4** are injected into the unit I. To the product leaving the unit I is added material component **5** for treatment in unit II. The product from unit II is injected in divided streams into unit V. Material components **6**, **7**, **8** and **9** are similarly injected for treatment in unit III and to the product leaving this unit is added material component **10** for treatment in unit IV which discharges again in divided streams into unit V for final treatment therein. Unit V discharges into the streamcurrent chamber indicated in Fig. 6 and in the above noted formula by "SC." We have in this case series operation of units I—II and III—IV, respectively, and parallel operation of units I and III each for the treatment of four material components, and units II and IV for treatment of the products from units I and III plus material components added to each. Both units II and IV are connected in series with the final treatment unit V into which they discharge in divided streams.

The division and subdivision of the material streams passing into the various units is indicated in Fig. 6, but is neglected in Formula A. For the sake of completeness, such division and subdivision may for this particular case be represented by the Formula A_1, noted below, which approaches more accurately the conditions illustrated in Fig. 6:

$$(A_1)\qquad \left.\begin{array}{l} \left.\begin{array}{l}1\longrightarrow \mathrm{I}\\ 2\ +4\rightarrow \mathrm{I}\\ 3\longrightarrow \mathrm{I}\end{array}\right\}P_{\mathrm{I}}\quad \left\{\begin{array}{l}Fa\longrightarrow \mathrm{II}\\ Fb\ +5\rightarrow \mathrm{II}\\ Fc\longrightarrow \mathrm{II}\end{array}\right\}P_{\mathrm{II}}\\[2ex] \left.\begin{array}{l}6\longrightarrow \mathrm{III}\\ 7\ +9\rightarrow \mathrm{III}\\ 8\longrightarrow \mathrm{III}\end{array}\right\}P_{\mathrm{III}}\left\{\begin{array}{l}Fa\longrightarrow \mathrm{IV}\\ Fb+10\rightarrow \mathrm{IV}\\ Fc\longrightarrow \mathrm{IV}\end{array}\right\}P_{\mathrm{IV}} \end{array}\right\}P_{\mathrm{II}}+P_{\mathrm{IV}}\left\{\begin{array}{l}Fa\longrightarrow \mathrm{V}\\ Fb\longrightarrow \mathrm{V}\\ Fc\longrightarrow \mathrm{V}\end{array}\right\}P_{\mathrm{V}}\rightarrow SC$$

It will be seen that the Formula A_1 is merely an elaboration of Formula A. It shows that the initial material components **1**, **2**+**4**, **3** and **6**, **7**+**9**, **8** are fed into the handling units I and III, respectively, in divided streams, as is also apparent from Fig. 6. The products P_{I} and P_{III} coming from the units I and III, respectively, are again divided each into three fractions Fa, Fb, Fc, and these fractions are separately fed into and passed through the units II and IV, respectively. Material component **5** is added to fraction Fb of the product P_{I} coming from unit I, and material component **10** is added to fraction Fb of the product P_{III} coming from unit III. The products P_{II} and P_{IV} coming from units II and IV are united, and the resulting product $P_{\mathrm{II}}+P_{\mathrm{IV}}$ is again subdivided into fractions Fa, Fb, Fc for passage through the handling unit V. The product P_{V} from this unit is discharged into the streamcurrent chamber SC.

The further subdivision of the material streams within each handling unit, that is to say, the ejection of two streams in the form of a plurality of jets for turbulent intermixture with the third stream in each unit, is omitted in Formula A_1 because symbols representing such subdivision would render the formula unduly complicated. If it is assumed, for example, that the valves in each handling unit provide for twenty sets of ports or jets, each set having five jets, then we obtain a subdivision of each of the two material components, e. g., components 1 and 3 in handling unit I, into one hundred jets or streams which intermix with the material stream comprising the components 2+4. Each handling unit therefore subdivides the material components fed into it, into two hundred parts. The serial connection of handling units I, II, V and III, IV, V, respectively, as shown in Fig. 6 and as symbolized in Formulae A and A_1, therefore furnishes a rational breakdown or subdivision of the material components in three stages of two hundred subdivisions each.

Additional examples of interconnecting and operating the handling units will be briefly discussed below, merely by reference to simplified formulae along the lines of Formula A. It is understood, however, that each formula is to be read as if it contained symbols for the division and subdivision of the material streams such as indicated in Formula A_1, and in addition thereto symbols for the further subdivision which occurs within each handling unit to obtain the turbulent intermixture of the separate material streams or fractions flowing therethrough.

The next case to be considered, in the light of the above remarks, is concerned with treating a plurality of material components in a straight series connection of the various handling units I–V, with material components added at each stage according to the formula

$$\text{(B)}\quad 1+2+3+4\rightarrow \mathrm{I}\rightarrow +5\rightarrow \mathrm{II}\rightarrow +6\rightarrow \mathrm{III}\rightarrow +7\rightarrow \mathrm{IV}\rightarrow +8\rightarrow \mathrm{V}\rightarrow \mathrm{SC}$$

wherein the Arabic numerals again indicate the material components and the Roman numerals indicate the treating or handling units. It will be seen that in such embodiment material components 1, 2, 3 and 4 are treated in unit I, which discharges in divided streams to the second stage II, to which is added material component 5. To the product from unit II is added material component 6 for treatment in unit III. To the product from unit III is added material component 7 for treatment in unit IV. To the product from unit IV is added material component 8 for final treatment in unit V, which discharges into the streamcurrent chamber SC.

A further possibility is presented by interconnecting the available mixing or treating units, e. g., units I–V in series connection so that treatment in stages is obtained, and adding at each of the first four stages a plurality of, say, four material components according to the formula

$$\text{(C)}\quad \begin{array}{l} 1+2+3+4\rightarrow \mathrm{I}\rightarrow +5+6+7+8\rightarrow \mathrm{II} \\ \quad \mathrm{II}\rightarrow +9+10+11+12\rightarrow \mathrm{III}\rightarrow +13+14+15+16\rightarrow \mathrm{IV}\rightarrow \mathrm{V}\rightarrow \mathrm{SC} \end{array}$$

Materials difficult to blend or mix may be treated by interconnecting mixing units so that fractions of products leaving the successive units or stages may be re-circulated, for example, according to the formula

$$\text{(D)}\quad \begin{array}{l} 1+2+3\rightarrow \mathrm{I}\rightarrow F_{Ia}\rightarrow \mathrm{II}\rightarrow F_{IIa}\rightarrow \mathrm{III}\rightarrow F_{IIIa}\rightarrow \mathrm{IV}\rightarrow F_{IVa}\rightarrow \mathrm{V}\rightarrow \mathrm{SC} \\ \qquad\quad \mathrm{I}\leftarrow F_{Ib}\quad \mathrm{II}\leftarrow F_{IIb}\quad \mathrm{III}\leftarrow F_{IIIb}\quad \mathrm{IV}\leftarrow F_{IVb} \end{array}$$

wherein it is assumed that three material components 1, 2 and 3 are to be handled. These components are treated first in unit I. A fraction of the product leaving unit I, indicated in the above formula by "F_{Ia}" is injected in divided streams for treatment in unit II; a fraction of the product leaving unit II, indicated by "F_{IIa}," is injected in divided streams for treatment in unit III; a fraction of the product leaving unit III, indicated at "F_{IIIa}," is conducted in divided streams to unit IV for treatment therein; a fraction "F_{IVa}" is directed in divided streams for final treatment in unit V. Unit V then discharges into the streamcurrent chamber SC. Fractions F_{Ib}—F_{IVb} of the products leaving units I–IV, respectively, are re-circulated through the respective units, as indicated in Formula D.

Materials difficult to blend may also be treated in accordance with the formula

$$\text{(E)}\quad \left.\begin{matrix} 1\rightarrow \\ 2\rightarrow \\ 3\rightarrow \end{matrix}\right\}\rightarrow \mathrm{I}\rightarrow \left\{\begin{matrix} \rightarrow F_{Ia}\rightarrow \mathrm{II}\rightarrow \\ \rightarrow F_{Ib}\rightarrow \mathrm{III}\rightarrow \\ \rightarrow F_{Ic}\rightarrow \mathrm{IV}\rightarrow \end{matrix}\right\}\rightarrow \mathrm{V}\rightarrow \mathrm{SC}$$

wherein the three components 1, 2 and 3 are injected in divided streams for treatment in unit I. The product leaving unit I is divided into three fractions—F_{Ia}, F_{Ib}, F_{Ic}—which are directed for treatment, each in divided streams, to the units II, III and IV, respectively. These latter units discharge in common, but in divided streams, into the final treatment unit V. We have thus a series connection of units I, II, V with units III and IV operating in parallel with unit II.

One more case may be cited in order to indicate the adaptability and flexibility of the invention in the intermixing and blending of materials. Again it may be assumed that three material components, which are difficult to mix, are to be treated. This may be done according to the formula

$$\text{(F)}\quad \begin{array}{l} \left.\begin{matrix} 1\rightarrow \\ 2\rightarrow \\ 3\rightarrow \end{matrix}\right\}\rightarrow \mathrm{I}\rightarrow \left\{\begin{matrix} F_{Ia}\rightarrow \mathrm{II}\rightarrow F_{IIa}\rightarrow \\ F_{Ib}\rightarrow \mathrm{III}\rightarrow F_{IIIa}\rightarrow \\ F_{Ic}\rightarrow \mathrm{IV}\rightarrow F_{IVa}\rightarrow \end{matrix}\right\}\rightarrow \mathrm{V}\rightarrow \mathrm{SC} \\ \qquad\quad \mathrm{I}\leftarrow F_{Id} \\ \qquad\quad \mathrm{I}\longleftarrow\!\!\longleftarrow\!\!\longleftarrow F_{IIb} \\ \qquad\qquad\qquad\quad \mathrm{II}\leftarrow F_{IIIb} \\ \qquad\qquad\qquad\quad \mathrm{III}\leftarrow F_{IVb} \end{array}$$

wherein the three material components are first conducted into unit I for treatment therein. The product leaving unit I is again divided into fractions F_{Ia}, F_{Ib}, and F_{Ic}, as in case "E" for treatment, respectively, in the units II, III, IV. The product coming from these units is, however, again divided into fractions F_{IIa}, F_{IIIa}, F_{IVa}, for final treatment in unit V, while fractions F_{IIb}, F_{IIIb}, and F_{IVb} are re-circulated through the units I, II, III, respectively. A fraction F_{Id} of the product coming from unit I may likewise be re-circulated through this unit.

It is understood, of course, that suitable pipes, valves, and pumps, as required, are provided for obtaining the interconnection of the units, as described. Likewise, if pressure and temperature controls are required, such controls may be provided wherever needed. In the event that the units are operated with different pressures, suitable means such as check valves are provided in the corresponding interconnecting pipes and conduits.

The above description of the possibilities of the embodiment, Fig. 6, is rendered merely for the purpose of giving examples of operation. These examples show typical cases but could easily be multiplied. The number of mixing units may be varied and their operative use may be varied. For example, five units may be provided, but only three units may be used in any one example described above.

It will be appreciated that the approach as indicated in the various formulae permits complete supervision of complex mixing, blending, homogenizing, etc., processes and reproduction of such processes with reasonable certainty of obtaining identical results. Guesswork is largely eliminated. The invention thus provides means for the application of rational thought and procedure throughout the planning, execution and repetition or reproduction of such processes.

The apparatus may be furnished in any desired size and for satisfying any, even the most exacting and most complex requirements. Materials may be intermixed or blended in a single pass or by turnover circulation of fractions of the material body in the streamcurrent chamber or of the entire contents of the chamber. The homogeneity of the final product in the streamcurrent chamber is maintained by controlled hydraulic displacement, as a by-product of the withdrawal of material. The apparatus disclosed herein, e. g., in Fig. 2, will be found suitable, in many cases, to perform the work heretofore performed by apparatus of the colloid-mill type.

It may be mentioned, in conclusion, that the adaptability and flexibility of the invention with regard to structural expressions removes limitations formerly imposed on the ingenuity of the designer. This holds true so far as use of materials is concerned as well as to physical features, shape of the structure and placement in any given environment.

Changes may be made within the scope and spirit of the following claims in which is defined what is believed to be new and desired to have protected by Letters Patent of the United States.

I claim:

1. Apparatus for handling materials comprising a tank, means forming two separate material-supply conduits extending into said tank and defining an open-ended passageway which is disposed between the conduits and substantially of the same length as the conduits, the walls of said conduits being provided with ports which communicate with said passageway, means for feeding material into said passageway for unimpeded discharge directly into said tank, and means for feeding material into said material-supply conduits for injection through said ports into said passageway.

2. The structure and combination defined in claim 1, together with valve means for controlling the injection of material from said material-supply conduits through said ports into said passageway.

3. The structure and combination defined in claim 1, wherein the ports in the walls of said material-supply conduits are inclined so as to inject the material therefrom into said passageway at an acute angle and tangentially in opposition to the direction of flow of material through the passageway.

4. The structure and combination defined in claim 1, together with means for separately selectively withdrawing adjustable amounts of material from a plurality of predetermined levels of the fluid body of material formed in said tank and selectively directing such withdrawn amounts for re-circulation through said material-supply conduits and/or through said passageway and/or for discharge from the tank.

5. Hydraulic material handling apparatus comprising a tank having an inlet for downwardly feeding fluid material thereinto, means forming in said tank an inner chamber for receiving material from said inlet, means on the outside of said inner chamber forming a plurality of vertically superposed manifolds each communicating with said chamber at a corresponding vertical level thereof for draining fluid material therefrom, valve means for each manifold to control the amount of material to be drained therethrough, means forming a compartment at the top of said chamber which communicates with the fluid body therein, means for selectively withdrawing adjusted amounts of fluid material from said chamber through said manifolds, and means for directing withdrawn amounts of material selectively for re-circulation through said inlet and/or for re-injection through said compartment and/or for discharge.

6. A device for intermixing materials comprising a plurality of coaxial tubes forming a central axially extending material-supply conduit and an annular coaxial material-supply conduit surrounding said centrally axially extending conduit and defining therewith an annular open-ended passageway which separates said conduits in radial direction, means for selectively feeding material separately into said material-supply conduits and into said passageway, respectively, and ports disposed in the walls of the tubes forming said material-supply conduits for directing the material fed thereinto generally radially into said passageway to form a plurality of generally radially directed jets for collision with the material fed into and flowing through said passageway.

7. The structure and combination defined in claim 6, together with valve means for adjusting said ports to determine the intensity of said jets.

8. The structure and combination defined in claim 6, together with coaxial valve tubes for coaction with the walls of the tubes forming said material-supply conduits, ports in said last named coaxial valve tubes for coaction with the ports in the walls of said conduits, means for operating said valve tubes for the purpose of adjusting the outflow of material from the ports in said conduits into said passageway, means for journalling said valve tubes, and means for centering and for supporting all of said tubes.

9. A device for intermixing fluid materials comprising a pair of coaxial radially spaced movable tubes forming an annular axially extending passageway, ports in said tubes, means for injecting material through said ports for intermixture within said passageway, and means for moving said tubes to control the injection of material through the ports thereof.

10. In a material-handling apparatus, means forming a first vertically extending chamber for receiving fluid material for down-flow therein, means forming a second vertically extending chamber, means for transferring material from selected levels of said first chamber into said second chamber; and means forming an upwardly inclined passageway for receiving material from either or both of said chambers for upflow therein.

11. A material-handling apparatus comprising means forming a vertically disposed downwardly tapering inlet for receiving a fluid material for down-flow therein, means extending from the bottom of said inlet and forming an upwardly inclined upwardly uniformly widening passageway, and valve means at the juncture of said inlet and said passageway for transferring fluid material from said inlet into said passageway for upflow therein.

12. A material-handling apparatus comprising means forming a vertically disposed downwardly tapering inlet for receiving fluid material for down-flow therein, means extending from the bottom of said inlet and forming an upwardly inclined upwardly uniformly widening passageway, valve means disposed at the juncture of said inlet and said passageway for transferring material from said inlet into said passageway for upflow therein, and means for injecting fluid into

said inclined passageway for intermixture with the material flowing therethrough.

13. Apparatus for handling fluid materials comprising means forming a vertically extending inlet for receiving fluid material for downflow therein and outflow therefrom at the bottom thereof, means forming a chamber having a floor which connects with portions of said inlet at the bottom thereof and which extends therefrom upwardly and laterally outwardly, for receiving material from said inlet for upflow therein, and baffle means disposed in said chamber transversely above the floor thereof and vertically spaced therefrom for controlling the upward and laterally outward flow of material therethrough.

14. The structure and combination defined in claim 13, wherein said baffle means is a platelike member disposed above said floor and extending substantially in parallel therewith for a major portion of the length thereof.

15. The structure and combination defined in claim 13 together with means for adjusting the angular position of said baffle means relative to the plane of said floor.

16. A device for intermixing liquid materials comprising means forming a plurality of confined elongated material-receiving conduits, means forming an open-ended passageway which extends substantially in parallel with said conduits substantially throughout the length thereof, there being ports in the wall of each of said conduits chambers which communicate with said passageway, means for directing liquid material into each of said conduits for ejection therefrom through said ports into said passageway, and means forming a chamber for receiving the liquid material which issues from the open end of said passageway.

17. A device for intermixing liquid materials comprising tubular means defining a central axially extending inner chamber, tubular means disposed in radially spaced relationship with respect to the tubular means defining said inner chamber and forming therewith an annular intermediate chamber which extends coaxial with and surrounds said inner chamber, means disposed in radially spaced relationship with respect to the tubular means defining said intermediate chamber and forming an outer chamber which extends in parallel with said intermediate chamber substantially throughout the length thereof, and ports in the walls of said tubular means for establishing hydraulic communication between said chambers.

18. In apparatus for handling materials, means forming two separate material supply conduits and defining a passageway which is disposed between said conduits and substantially of the same length as the conduits, there being ports in the walls of said conduits which communicate with said passageway along spaced intervals thereof, means for injecting material into one of said conduits at one end thereof for discharge into said passageway through the ports in the walls thereof, and means for injecting material into the other conduit at the opposite end thereof for discharge into said passageway through the ports in the wall of such other conduit.

19. Apparatus for handling fluid materials comprising a tank, means forming a flow-distributing wall disposed within the tank which extends generally upwardly and laterally outwardly and forms an inner chamber therein, an inlet extending into said tank for downwardly feeding material into said inner chamber to form a fluid body therein, said flow-distributing wall being provided with vertically superposed outlets for draining material from a plurality of levels of the fluid body contained in said inner chamber, means including the outer tank wall forming a plurality of discharge chambers, one for receiving fluid material from each level of said fluid body through the corresponding outlets in said flow-distributing wall, and means for adjustably controlling the amount of fluid material which is to be discharged from each of said discharge chambers.

20. Apparatus for handling materials comprising a tank, means forming in said tank a generally upwardly and laterally outwardly extending flow-distributing wall which defines an inner chamber therein, an inlet for downwardly feeding material into said inner chamber to form a fluid body therein, said flow-distributing wall being provided with outlets disposed at vertically spaced levels for draining material from said inner chamber, means including the outer tank wall forming a plurality of discharge chambers, one for receiving fluid material from each level of said fluid body through the corresponding outlets in said flow-distributing wall, and means for adjustably controlling the amount of fluid material material which is to be discharged from each of said discharge chambers to regulate the flow of material from said outlets in said flow-distributing wall for the purpose of controlling the upwardly and laterally outwardly directed hydraulic displacement of the fluid body in said inner chamber.

21. Apparatus for handling materials comprising a unitary tank, means forming in said tank an upwardly and laterally outwardly extending flow-distributing wall defining therein an inner chamber, means forming an inlet extending into said tank for downwardly feeding material into said inner chamber to form a fluid body therein, said flow-distributing wall being provided with vertically superposed outlets for draining material from a plurality of levels of the fluid body contained in said inner chamber, the outer tank wall forming with said flow-distributing wall an outer chamber, means in said outer chamber forming a plurality of vertically superposed compartments, one for receiving material to be drained from each of said levels, and means associated with each compartment for controlling the passage of material therethrough to regulate the flow of material from said outlets in said flow-distributing wall for the purpose of controlling the upwardly and laterally outwardly directed hydraulic displacement of the fluid body in said inner chamber.

22. Hydraulic material handling apparatus comprising a tank forming a flow-distributing wall which extends from the bottom upwardly and generally laterally outwardly forming the floor of an inner tank chamber, inlet means extending into said inner chamber for downwardly feeding fluid material thereinto to form a fluid body therein, said flow-distributing wall being provided with vertically spaced outlet areas for draining material from a plurality of corresponding levels of said fluid body, means associated with said flow-distributing wall on the outside thereof and forming a plurality of vertically superposed discharge chambers one for each outlet area, each discharge chamber communicating hydraulically with said fluid body at the corresponding vertical level thereof, and means associated with each discharge chamber for con-

trolling the amount of fluid material to be discharged therethrough to regulate the upwardly and laterally outwardly directed hydraulic displacement of said fluid body.

23. A material handling device comprising a pair of coaxially arranged tubes forming an elongated axially extending annular passageway, means for injecting fluid material at one end of said passageway for passage therethrough, means forming a chamber for receiving the material stream from the other end of said annular passageway, ports formed in each of said tubes along axially spaced intervals thereof, and means associated with said tubes for injecting fluid material generally radially through the ports thereof for intermixture with the material stream conveyed through said passageway.

24. Apparatus for mixing or blending a plurality of fluid materials comprising a plurality of coaxial disposed tubular means forming an axially extending inner fluid receiving chamber and an annular outer fluid-receiving chamber surrounding said inner chamber and radially spaced therefrom, ports formed in the wall of said inner chamber and ports formed in the inner wall of said outer chamber, and means for directing fluids separately into each of said chambers for discharge therefrom through said ports into radial space between said chambers for turbulent intermixture therein.

25. Apparatus for mixing or blending a plurality of fluid materials comprising means forming a mixing chamber, means associated with the walls of said mixing chamber forming a plurality of fluid-receiving chambers which extend substantially in parallel with said mixing chamber, said fluid-receiving chambers being hydraulically in communication with said mixing chamber through ports formed in the walls of said chambers, means for directing fluid materials separately into each of said fluid-receiving chambers for discharge therefrom through said ports into said mixing chamber for turbulent intermixture therein, means forming a collecting chamber for receiving the intermixed product from said mixing chamber to form a fluid body thereof, and means associated with said collecting chamber for selectively withdrawing adjusted amounts of intermixed fluid material from selected levels of said fluid body and selectively directing such withdrawn amounts for discharge and/or for reinjection selectively into either of said fluid-receiving chambers and/or into said mixing chamber.

26. Apparatus for handling fluid material comprising a tank forming an upwardly and laterally outwardly sloping floor, means forming an inlet extending into said tank for feeding liquid thereinto to form a fluid body therein, means associated with said floor outside thereof forming a plurality of discharge chambers for withdrawing adjusted amounts of liquid from said fluid body at a plurality of vertically spaced levels thereof to cause hydraulic displacement in said fluid body which extends from said inlet generally laterally outwardly to and into said discharge chambers, means forming a plurality of baffle members vertically spaced from said floor and extending transversely through said fluid body for controlling the direction of said hydraulic displacement, and means for adjusting the angular positions of said baffle members relative to the plane of said floor.

27. A device for intermixing a plurality of liquids comprising a plurality of coaxially arranged members forming a plurality of elongated tubular chambers and an open-ended passageway which extends in parallel with said chambers substantially throughout the length thereof, ports at said members communicating with said passageway, means at one end of said device for separately feeding adjusted amounts of liquids into said chambers for outflow through said ports into said passageway for intermixture therein, closure means at the opposite end of said device forming a compartment for receiving the liquid product intermixed in said passageway and issuing from the open end thereof, and conduit means for withdrawing such product from said compartment.

28. Apparatus for mixing or blending a plurality of fluid materials comprising means forming a mixing chamber, means associated with the wall of said mixing chamber forming a plurality of fluid-receiving chambers which extend substantially in parallel with said mixing chamber, said fluid-receiving chambers being hydraulically in communication with said mixing chamber through ports formed in the walls of said chambers, means for directing fluid material into said mixing chamber for passage therethrough, and means for directing fluid materials separately into each of said fluid-receiving chambers for discharge therefrom through said ports into said mixing chamber for turbulent intermixture therein with the fluid material injected into said mixing chamber.

29. Device for intermixing fluid materials comprising wall means forming a first material-receiving chamber, wall means forming a second material-receiving chamber which is substantially coextensive with said first chamber and forms a unitary and rigid structure therewith, wall means disposed adjacent to and contacting portions of the wall means of said first and said second material-receiving chambers forming an independent passageway which is common to said chambers and substantially coextensive therewith, communicating ports formed in the wall means of said material-receiving chambers and said passageway, means for independently and separately injecting fluid material components into each of said material-receiving chambers for outflow in divided streams through said ports into said passageway for intermixture therein, and means for removing the intermixed fluid product from said passageway.

30. The structure and combination defined in claim 29 together with means for separately injecting a fluid material component into said passageway for intermixing with the material components injected thereinto from said material-receiving chambers through said ports.

31. Device for intermixing fluid materials comprising a pair of movable wall members defining the lateral limits of a passageway which is open at one end thereof, a stationary material-receiving chamber associated with each of said wall members and having a wall portion adjacent thereto, ports formed in the wall portion of each material-receiving chamber for coaction with ports formed in the associated wall member of said passageway, means for separately injecting fluid material components into said material-receiving chambers for lateral outflow through said ports into said passageway, mean for moving said movable wall members to adjust the ports therein relative to coacting ports in the respective wall portions of the associated stationary material-receiving chambers to regulate the lat-

eral outflow of said fluid material components from said material-receiving chambers through said ports into said passageway for turbulent intermixture therein, and means for removing the intermixed product from the open end of said passageway.

32. The structure and combination defined in claim 31 together with means for separately injecting a fluid material component into said passageway for passage therethrough and intermixture therein with the material components injected thereinto through said ports.

33. Device for intermixing fluid materials comprising wall means forming two individual material-receiving chambers, means for securing said chambers in relatively stationary position to form a unitary structure, means associated with said material-receiving chambers forming an interiorly entirely unobstructed passageway which is open at one end and constitutes a mixing chamber common to said material-receiving chambers, ports formed in a wall portion of each material-receiving chamber communicating with said passageway and mixing chamber, means for separately injecting fluid material components into said material-receiving chambers for outflow in divided streams through said ports into said common passageway and mixing chamber, the axes of the ports formed in the wall portions of the respective material-receiving chambers being disposed at angles to cause collision in said passageway and mixing chamber of the divided streams of material issuing respectively therefrom for intimate intermixture of said fluid material components, and means for removing the intermixed product from the open end of said passageway and mixing chamber.

34. The structure and combination defined in claim 33 together with valve means forming part of said passageway and mixing chamber, and means for adjusting said valve means to regulate the outflow of said divided material streams from said ports into said passageway and mixing chamber.

35. The structure and combination defined in claim 33 together with means for separately injecting a fluid material component into said passageway and mixing chamber for passage therethrough and intermixture therein with the material components delivered through said ports.

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