Oct. 9, 1962 A. G. GILBERT 3,057,476

HYDROCYCLONES

Filed May 29, 1959 3 Sheets-Sheet 1

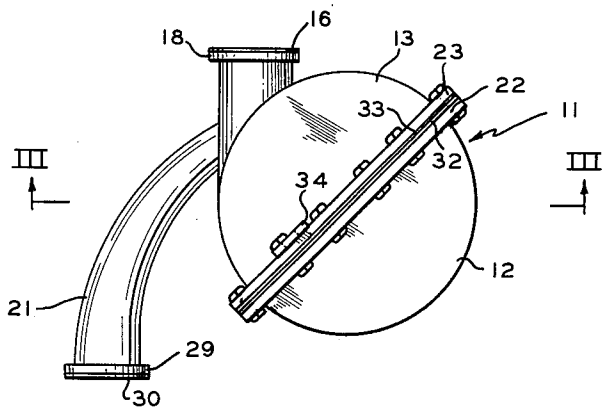


FIG. 1

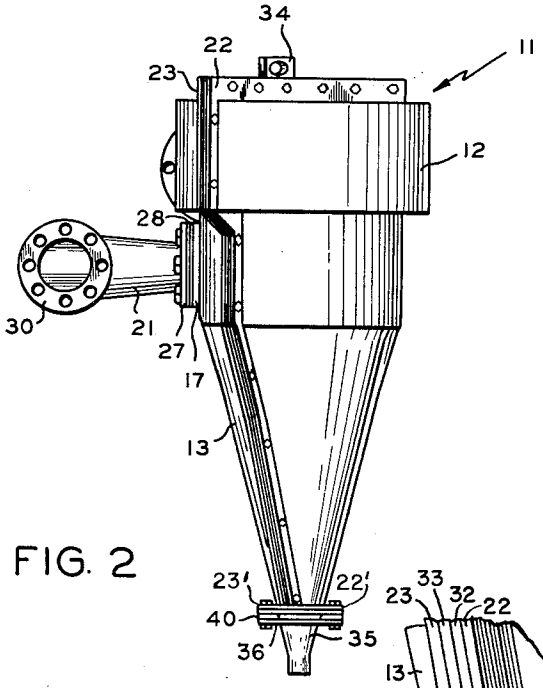


FIG. 2

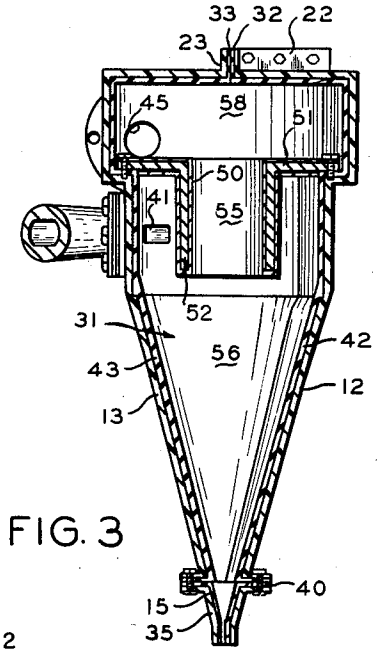


FIG. 3

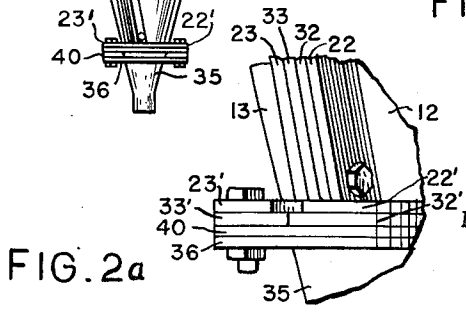


FIG. 2a

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Oct. 9, 1962 A. G. GILBERT 3,057,476

HYDROCYCLONES

Filed May 29, 1959 3 Sheets-Sheet 2

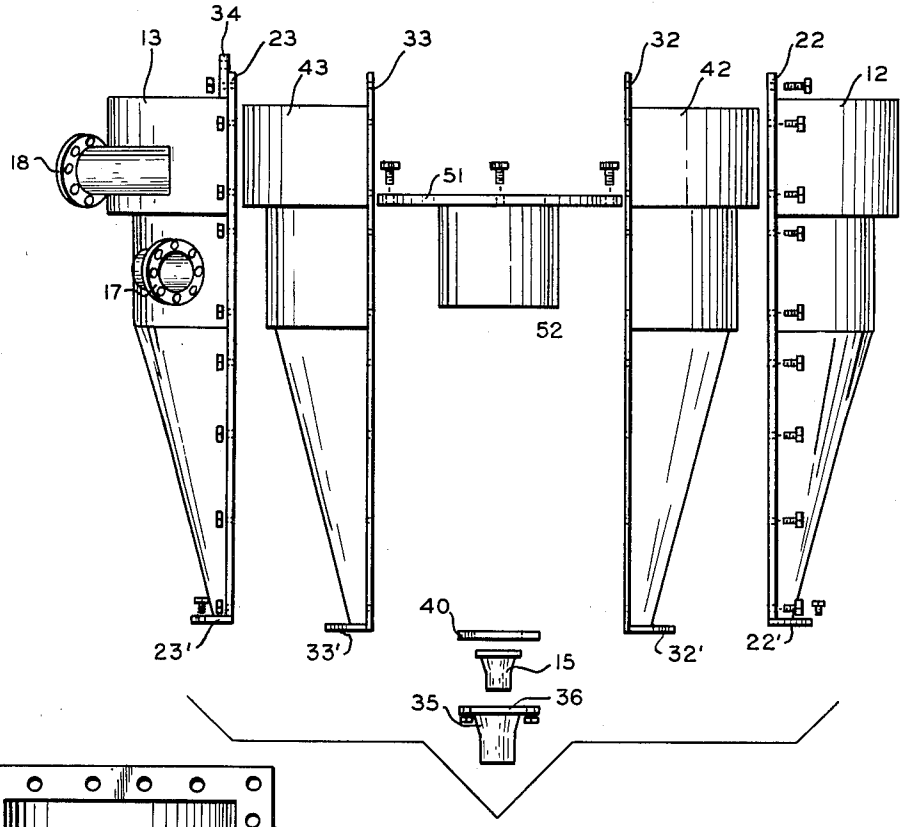


FIG. 4

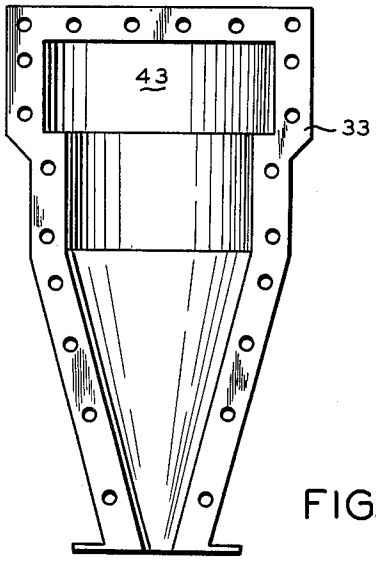


FIG. 6

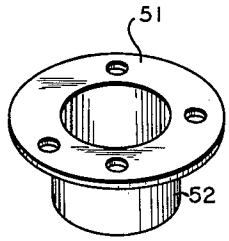


FIG. 5

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HYDROCYCLONES

Filed May 29, 1959 3 Sheets-Sheet 3

FIG. 7

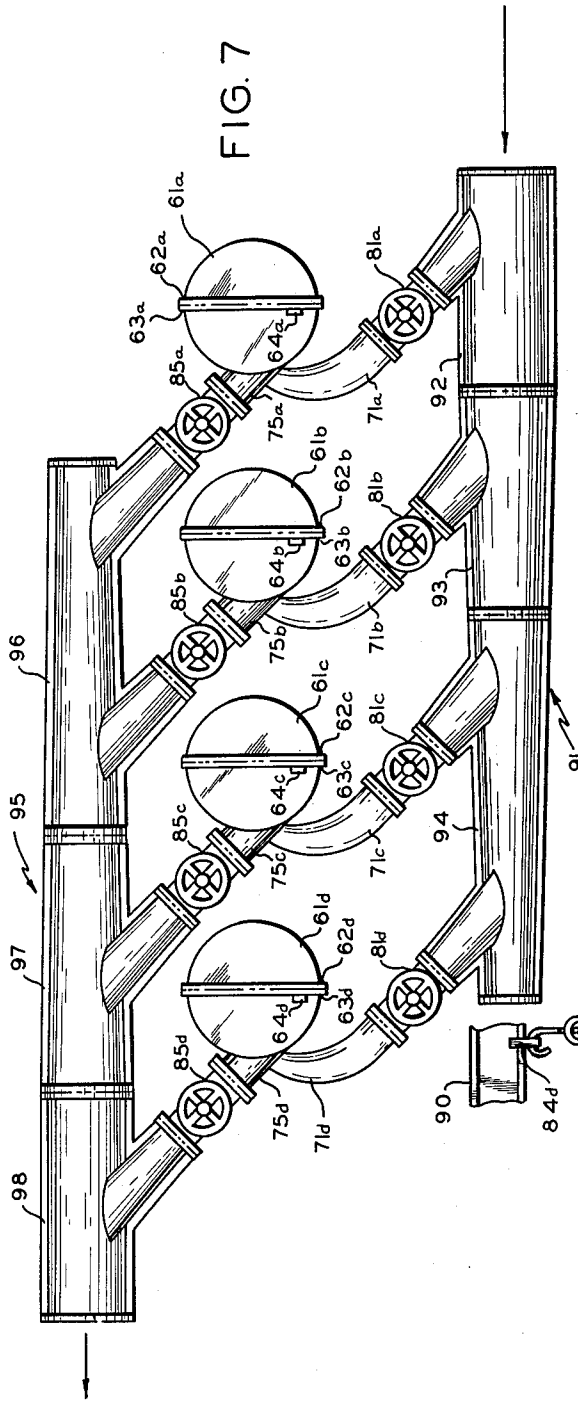
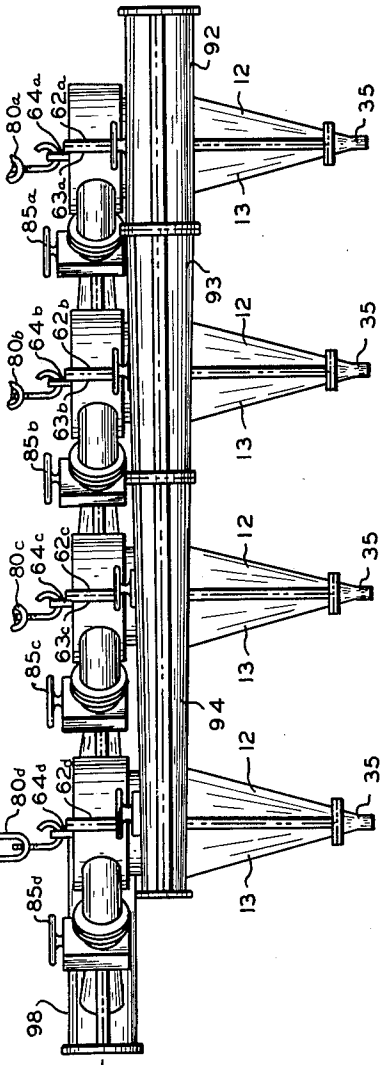


FIG. 8



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United States Patent Office

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HYDROCYCLONES

Alfred G. Gilbert, Bridgeville, Pa., assignor of one-half to Charles Augustus McClure, Malvern, Pa.

Filed May 29, 1959, Ser. No. 816,899
12 Claims. (Cl. 209—211)

This invention relates to hydraulic classifying and separating apparatus, herein called "hydrocyclones" or merely "cyclones," and concerns especially improved construction and interconnection thereof. As conventionally constructed and arranged, hydrocyclones are difficult to assemble and to interconnect, and it is especially time-consuming to disassemble them wholly or partly as required for inspection, maintenance, and repair. It is usual to fabricate each cyclone as a plurality of ring-like metal housing pieces, with or without a separate tubular piece of rubber as a liner, and to connect several cyclones in parallel to a common manifold. Alignment and interconnection of the respective pieces of the cyclones and of them and their manifolds with the interconnecting conduits is unnecessarily laborious. Uneven wear of the various pieces of such construction necessitates substantially complete disassembly and consequent costly "down" time.

A primary object of the present invention is improvement in the construction and arrangement of hydrocyclones. An object is fabrication of a cyclone in a plurality of segmental pieces for ready assembly and disassembly. A particular object is provision of an improved lined cyclone. Another object is simplified manifolding of hydrocyclones. Other objects of this invention, together with means and methods for attaining the various objects, will be apparent from the following description and the accompanying diagrams.

FIG. 1 is a plan of a hydrocyclone of this invention including infeed conduit; FIG. 2 is an elevation of the apparatus of FIG. 1; FIG. 2*a* is a detail view on an enlarged scale of the lower left flanged portion of the apparatus of FIG. 2; and FIG. 3 is a longitudinal (axial) section of the same apparatus taken at III—III of FIG. 1. FIG. 4 is an exploded elevational view of the cyclone of the preceding views; FIG. 5 is a perspective of a head plate visible in elevation in FIG. 4; and FIG. 6 is a rear elevation of the front (right) segment of the liner shown in FIG. 4. FIG. 7 is a plan of a plurality of cyclones interconnected by conduits and manifolds according to this invention, and FIG. 8 is an elevation (partly broken away) of the apparatus in FIG. 7.

In general, the objects of the present invention are accomplished by provision of a hydrocyclone having an inlet conduit and an overflow outlet conduit and comprising a plurality of housing segments, symmetrical with respect to the axis of the hydrocyclone, the plurality of segments fitting against one another about the axis to form an enclosed housing thereabout having an underflow outlet, the inlet and overflow outlet conduits interconnecting to one of the segments for intercommunication with the interior of the housing. This is accomplished especially in conjunction with a removable resilient lining fabricated in a like plurality of segments. The invention contemplates also a plurality of such cyclones aligned side-by-side, an infeed manifold extending along the aligned cyclones, and infeed conduits connecting the respective cyclones to the infeed manifold, a substantially parallel overflow outlet manifold extending along the aligned cyclones, outlet conduits connecting the respective cyclones at an acute angle to the overflow outlet manifold, at least one of the conduits of each cyclone being curved between its junction with the cyclone and its junction with the manifold. Additional constructions and arrangements of cyclones as

comprehended by this invention also are illustrated and described hereinafter.

FIG. 1 shows hydrocyclone 11 in a plan (from the top). The cyclone housing comprises pair of segments 12, 13. Segment 12 at the lower right has an uninterrupted arcuate periphery, but segment 13 at the upper left is flanged at the side for connections to infeed conduit 21 and an overflow conduit (not visible in this view). Overflow flange 18 (facing rear) is located above infeed flange 17 (facing left, hidden) connected to conduit flange 27 with gasket 28 intervening (both similarly hidden in this view). Gasket 16 is shown in place against the face of overflow flange 18, and gasket 30 against the face of flange 29 at the opposite end of the infeed conduit, which tapers visibly from flange 29 toward the cyclone housing. At the top, segments 12 and 13 terminate in flanges 22 and 23, respectively, between which appear corresponding flanges 32 and 33 of the segments of liner 31, shown more fully in subsequent views. Flange 23 of the housing has hanger piece 34 (with eye) attached to the side of and extending above it.

FIG. 2 shows in elevation the cyclone and connected infeed conduit of FIG. 1, with the curved conduit shown end-on. Visible in addition to the components previously mentioned or shown is generally frustoconical underflow orifice holder 35, which terminates the housing at the horizontal portions of the bottom thereof. Top flange 36 of this piece is bolted to bottom flanges of the respective right and left housing segments, with gasket 40 and the horizontal portions of the left and right liner segments intervening. Previously shown flange 22 appears in elevation at the top, together with hanger piece 34 and just an edge of flange 23. The flanges are seen to extend down the left front of the housing, with the edges of flanges 32 and 33 of the liner sandwiched between them. The flanges of the indeed conduit and the infeed flange of the housing also appear in elevation at the left of this view. The segments of the housing comprise a cylindrical dome at the top of a cylindrical body portion, and a frustoconical portion, of corresponding diameter, intervening between and connecting the cylindrical body portion to the smaller, generally frustoconical underflow orifice holder.

FIG. 2*a* shows on an enlarged scale the encircled portion of the apparatus of FIG. 2. This detail view shows more clearly the relationship of the various flanges in the vicinity of the junction of the horizontal and oblique (nearly vertical) portions thereof. Flanges 22 and 23 of right and left housing segments 12 and 13, respectively, terminate in respective right and left horizontal portions 22′ and 23′, which immediately overlie right and left horizontal portions 32′ and 33′ of respective flanges 32 and 33 of the right and left liner segments. Next in order, from top to bottom of the horizontal elements bolted together near the bottom of the apparatus is gasket 40, which in turn is underlain by top flange 36 of underflow orifice holder 35.

FIG. 3 shows the same apparatus sectioned longitudinally along the axis as indicated in FIG. 1. Along the edges just inside the sectioned housing walls appear the walls of liner segments 42 and 43 at the right and left, respectively, which adjoin one another at the right inside the half-shell appearing in this view. Left segment 43 is interrupted at the middle left by rectangular infeed port 41 and at the upper left by circular overflow port 45. Head plate 51, which is shown more fully in FIGS. 4 and 5, has depending cylindrical "vortex finder" 52 surrounding overflow orifice 55, which interconnects body interior 56 and dome interior 58 of the cyclone. The head plate rests on the shoulder formed at the junction of the dome and body of the housing, where it is held in place by bolts threaded downward into the shoulder. The head plate, including the vortex finder, is cov-

ered with layer 50 of resilient material. Underflow orifice piece 15, which lines underflow orifice holder 35, also is visible in this view, together with gasket 40 surrounding the top of the orifice piece, interposed against the bottom face of the housing flanges with flanges of the liner intervening.

FIG. 4 shows the parts of the same cyclone in an elevational exploded view. The side flanges are oriented generally parallel to the side edges of the drawing, corresponding to a rotation of forty-five degrees in azimuth from the showing of the same parts in FIGS. 1 to 3. It is apparent that the segments of the liner are adapted to fit closely inside the segments of the housing, with the head plate surrounded thereby and with the underflow orifice piece underneath. FIG. 5 shows head plate 51 in perspective, oriented in azimuth as in FIGS. 1 to 3, revealing a more than ninety-degree spacing of two of four bolt holes through it, as is necessitated by the propinquity of the infeed port in the assembled cyclone. FIG. 6 shows front (right) segment 42 of the liner in rear elevation, showing the uninterrupted inside surface thereof.

The liner is made of suitable resilient material, such as natural or synthetic rubber or other elastomeric material, at least on the inner face thereof. This may be accomplished conveniently by laying up or molding the segments, depending upon the material used, as is customary in the manufacture of articles similarly composed. It is generally preferable to form each liner segment of a plurality of successive layers and to reinforce the outer surface or layers of such laminated construction. The lamination may be accomplished by dipping the exterior of the segment (or a layer thereof) in, or coating or spraying it with, a latex or solution of the elastomer or with other compatible material (e.g., polystyrene or the like) preferably containing flock or short fibers of ceramic or glass, linear high polymer, or similar reinforcing material. Properly constructed, a liner of this invention will stand under its own weight (i.e., be self-supporting) with the segments juxtaposed to one another as in the assembled position.

The housing may be made of any structurally satisfactory material, inasmuch as the liner receives and withstands the abrasive force during operation. Thus, aluminum or soft alloys may replace the usual steels or ceramics in the housing material, though preferably not in the piece used to provide the underflow orifice. Fabrication of the housing segments may be accomplished by casting or molding, deep-drawing or pressing, or by machining or other suitable method. Plastics, especially of fibre-reinforced composition are also useful as housing material, being cast or molded or being laid upon a form or template as is conventional. For example, housing segments may be made of polyester or epoxy or similar resin over (i.e., impregnating) glass fibres or similar reinforcing material, which may be in woven or non-woven form. The techinque of forming structurally sound fibre-reinforced plastics is well known from recent experience in the manufacture of boat hulls, car bodies, and the like.

Assembly of the elements of the apparatus herein described and illustrated is readily understood. The left or rear segment of the housing may be hung in place by any suitable means attached to the hanger piece on the top. The liner segment with matching infeed and overflow ports is fit snugly inside this housing segment. Then the head plate is set and bolted in place, after which the right front housing segment, with the matching liner segment fitted inside it, is placed about the head plate, juxtaposing the respective segment flanges. The illustrated nuts and bolts or other suitable fastening means are installed to hold the segments securely together and to the underflow orifice holder, as well as to install the connecting conduits. Disassembly to any desired degree may take place in the opposite sequence.

The segmental construction of the cyclones of this invention, including both housing and liner, greatly facilitates inspection of the apparatus, which may be carried out readily by unbolting the housing segment that is uninterrupted by conduit connections and removing it with the corresponding liner segment remaining inside it. If it is found necessary to insert a new liner, the head plate is readily removed to permit removal and replacement of the other liner segment, as well. If a segment of the housing should fail, which is especially unlikely in the fibre-reinforced plastic construction, it can be patched or replaced without replacement of the liner. Of course, three or more segments may be employed, instead of only two, in the housing and liner if desired; to secure the maximum benefits of this invention, the segments should extend for a major lengthwise (axial) portion of the cyclone, preferably from at or near the top to or near the bottom.

In operation, as in conventionally constructed hydrocyclones, a slurry of finely divided particulate solids is forced in through the infeed conduit into the body of the cyclone, where it swirls around the vortex finder, the denser or more massive particles migrating to the bottom and out through the underflow orifice, while the lighter or less massive particles migrate inward and upward into the dome through the orifice in the head plate, thence upward and out through the overflow orifice, together with the bulk of the liquid. In the apparatus of this invention the curved and tapered infeed conduit, whose cross section also preferably changes from circular to rectangular, while diminishing in area, assists in accelerating the infeed slurry as well as facilitating the connection of a plurality of cyclones in parallel, as hereinafter set forth. Curvature of infeed conduits according to this invention facilitates assembly and results in optimum utilization of space, especially where two or more cyclones are to be connected in parallel. It is preferred that the curvature be substantially constant over a major portion of the infeed conduit length and not less than about twice the radius of curvature of the cyclone at its junction with the conduit.

FIGS. 7 and 8 show in plan and elevation, respectively, four hydrocyclones having curved infeed conduits and straight overflow conduits connected to respective infeed and overflow manifolds. The manifold flow direction is from right to left both to and from cyclones 61*a*, 61*b*, 61*c*, 61*d*, as suggested by the arrows. Connected to the respective cyclones are tapered and curved infeed conduits 71*a*, 71*b*, 71*c*, 71*d*, and overflow conduits 75*a*, 75*b*, 75*c*, 75*d*, terminating respectively at valves 81*a*, 81*b*, 81*c*, 81*d*, and 85*a*, 85*b*, 85*c*, 85*d*, each valve being shown with an adjusting hand wheel. The infeed valves interconnect the infeed conduits with the infeed manifolds, and the overflow valves interconnect the overflow conduits with the overflow manifolds. The bolts or other fastening means for the various valve and cyclone connections are omitted from these views for simplicity of the showing. Hanger pieces 64*a*, 64*b*, 64*c*, 64*d* appear attached to flanges 63*a*, 63*b*, 63*c*, 63*d*, respectively, at the top of the respective cyclones, and flanges 62*a*, 62*b*, 62*c*, 62*d* of the opposite housing segments are juxtaposed to the flanges carrying the hanger pieces.

The respective infeed and overflow manifolds are identical, each being composed of three axially aligned tubular pieces and each tubular piece being formed of a like number of segments, bolted or otherwise fastened together. Thus, infeed manifold 91 comprises successive tubular pieces 92, 93, 94; while overflow manifold 95 comprises similar successive pieces 96, 97, 98. The manifold pieces are interrupted by ports oriented parallel to one another and at forty-five degrees to the line of flow, with two ports apiece in identical pieces 94 and 96 and one port in each of the other manifold pieces. Identical pieces 92, 98 preferably are substantially cylindrical throughout (being interrupted, of course, by the ports); the remaining tubular pieces taper with the object of maintaining uniform velocity of the slurry, the infeed pieces tapering in the

direction of flow and the outlet pieces tapering against the flow direction. The distance between successive ports along each manifold is constant, whether in successive pieces (as from **92** to **93**; and **97** to **98**) or in the same pieces (as in **94** and in **96**). It is apparent that the manifold junctions to the infeed conduits, which make a ninety-degree turn from the manifold to the cyclones, are parallel to the manifold junctions to the overflow conduits, which join the cyclones perpendicular (in a parallel plane) to the junctions of the infeed conduits. Hence, the infeed manifold ports have their axes oriented parallel to those of the overflow manifold ports.

As shown in FIG. 8, the cyclones are hung conveniently from I-beam **90** or the like by means of turnbuckles **80***a*, **80***b*, **80***c*, **80***d*, each of which comprises a conventional pair of oppositely threaded eye-bolts and a correspondingly threaded yoke. Clamps, such as visible clamp **84***d*, fit through the top of the bolts and fasten over the lower flange of the beam, and the respective lower eye-bolts pass through the eyes of the hanger pieces **64***a*, **64***b*, **64***c*, **64***d*, of the cyclones. After the cyclones are hung in this manner, the manifold and conduit connections may be made easily, with such minor adjustment in azimuth, height, or spacing as may be necessary or desirable. The underflow from the cyclones may be discharged onto a conveyor, into a trough, or, if desired, into a manifold or tank or other enclosed collecting device (not shown).

If it is desired to use fewer cyclones in parallel, one or more pieces of each manifold may be discarded as desired. Thus, for three cyclones, end pieces **92** and **98** of the infeed and overflow manifolds may be omitted, together with cyclone **61***d*, and the infeed manifold be displaced to the right by the distance of separation between successive ports, thereby connecting cyclone **61***a* to infeed manifold piece **93**, and cyclones **61***b* and **61***c* in that order to manifold piece **94**. The connection of the remaining cyclones to the overflow manifold would remain unchanged. Similarly, if the cyclones were to be manifolded in pairs, with cyclones **61***a*, **61***b* remaining connected to overflow manifold piece **96**, they also could be connected to infeed manifold piece **94**. The hydrocyclones of this invention may be modified to incorporate vent tubes, such as are disclosed in my copending patent application Serial No. 732,203, filed May 1, 1958, while retaining the benefits of both inventions. Other variations in construction and arrangement of the various apparatus elements disclosed herein may be made without departure from the inventive concept.

The claimed invention:

1. A plurality of hydrocyclones, each hydrocyclone comprising a plurality of conduits, including an infeed conduit and an overflow outlet conduit, a plurality of housing segments symmetrical with respect to the axis of the hydrocyclone, the plurality of segments fitting against one another about the axis to form an enclosed housing thereabout having an underflow outlet, the inlet and overflow outlet conduits interconnecting to one of the segments for intercommunication with the interior of the housing, the hydrocyclones being aligned side by side, an infeed manifold extending alongside the aligned cyclones, a substantially parallel overflow outlet manifold extending alongside the aligned cyclones, infeed conduits connecting the respective cyclones to the infeed manifold, and outlet conduits connecting the respective cyclones at an acute angle to the outlet manifold, at least one of the conduits of each cyclone being curved between its junction with the cyclone and its junction with the manifold.

2. A hydrocyclone manifold as in claim 1, comprising a plurality of axially aligned, essentially tubular pieces, at least one of which tapers in diameter from one end to the other, each piece being interconnected to the hydrocyclone by at least one conduit.

3. A manifold of the hydrocyclone of claim 1, comprising a plurality of axially aligned essentially tubular pieces, at least one of the pieces tapering in diameter from one end to the other, a piece so tapering having junctions for a plurality of hydrocyclone conduits.

4. The apparatus of claim 3 wherein the distance along the manifold between successive junctions for hydrocyclone conduits is fixed, both for successive junctions in the same piece and for successive junctions in successive pieces.

5. The apparatus of claim 1 wherein the line of junction of each infeed conduit with its manifold is parallel to the line of junction of the associated outlet conduit with its manifold, the lines of junction being viewed in a direction parallel to the axes of the cyclones.

6. The apparatus of claim 1 wherein the angle of junction of the respective infeed conduits to their manifold is an acute angle approximating the angle of junction of the respective outlet conduits to their manifold, the angles being viewed in a direction parallel to the axes of the cyclone.

7. The apparatus of claim 6 wherein the manifold for the infeed conduits and the manifold for the outlet conduits are substantially identical.

8. Hydrocyclone comprising a plurality of conduits, including an inlet conduit and an overflow outlet conduit, a plurality of housing segments symmetrical with respect to the axis of the hydrocyclone, the plurality of segments fitting against one another about the axis to form an enclosed housing thereabout having an under flow outlet, the inlet and overflow outlet conduits interconnecting to one of the segments for intercommunication with the interior of the housing.

9. Apparatus comprising a plurality of the hydrocyclones of claim 8 aligned side by side, an infeed manifold extending alongside the aligned cyclones, an outlet manifold extending alongside the aligned cyclones, substantially parallel to the infeed manifold, infeed conduits connecting the respective cyclones to the infeed manifold, and substantially straight outlet conduits connecting the respective cyclones to the outlet manifold.

10. The apparatus of claim 9 wherein the terminal portions of the infeed and outlet conduits of each cyclone, at their respective junctions with the respective manifolds, are oriented at an angle other than perpendicular to the axes of the manifolds and parallel to one another, when viewed in a direction parallel to the axis of the cyclone.

11. The apparatus of claim 8 wherein the housing comprises a frustoconical chamber and an intercommunicating dome, with the overflow outlet conduit interconnected to the dome and the inlet conduit interconnected to the frustoconical chamber, the housing segments extending longitudinally from the underflow outlet to and including a portion of the dome and extending circumferentially over a portion only of the arcuate periphery of the cyclone, at least one of the segments being removable separately from the rest of the cyclone, and means for retaining the removable segment assembled to the rest of the cyclone.

12. The apparatus of claim 11 wherein the portion of the dome not included in the removable segment is provided with means for suspending the cyclone from an overhead support.

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2,709,397	Banning	May 31, 1955
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UNITED STATES PATENT OFFICE

Certificate of Correction

Patent No. 3,057,476 October 9, 1962

Alfred G. Gilbert

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the drawings, Sheet 1, FIG. 2 should appear as shown below instead of as in the patent:

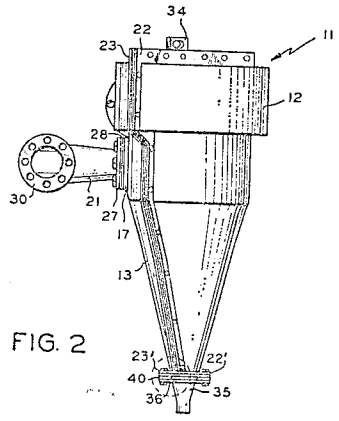


FIG. 2

column 2, line 3, strike out "a"; line 35, for "indeed" read —infeed—; same column 2, lines 26 and 27, for "horizontal portions of the bottom thereof. Top flange 36 of this piece is bolted to bottom flanges of the respective" read —bottom. Top flange 36 of this piece is bolted to the horizontal portions of the flange of the respective—; lines 39 and 40, for "a cylindrical body portion, and a frustoconical portion, of corresponding diameter, intervening between and connect-" read —a cylindrical body portion, of corresponding diameter, and a frustoconical portion intervening between and connect-—; column 3, line 5, after "with" insert —the—; line 51, for "upon" read —up on—; line 56, for "techinque" read —technique—; column 6, line 29, for "under flow" read —underflow—; the present claim numbers of the patent should be rearranged as follows:

Claim 8 should be claim 1	Claim 5 should be claim 7
Claim 11 should be claim 2	Claim 6 should be claim 8
Claim 12 should be claim 3	Claim 7 should be claim 9
Claim 9 should be claim 4	Claim 2 should be claim 10
Claim 10 should be claim 5	Claim 3 should be claim 11
Claim 1 should be claim 6	Claim 4 should be claim 12

column 6, under "UNITED STATES PATENTS," after line 70, insert

2,658,618	Vogel	Nov. 10, 1953

same column 6, after line 73, insert

2,816,658	Braun	Dec. 17, 1957

same column, after line 74, insert the following:

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254,790	Switzerland	Jan 3, 1949
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OTHER REFERENCES

Dorr-Oliver, Bulletin 2503, 1955 (Fig. 3), page 4.

Signed and sealed this 26th day of November 1963.

[SEAL]

Attest:

ERNEST W. SWIDER,
Attesting Officer.

EDWIN L. REYNOLDS,
Acting Commissioner of Patents.