Dec. 12, 1961 H. U. ZIEMER 3,012,670

FLOTATION APPARATUS

Filed Aug. 31, 1959 2 Sheets-Sheet 1

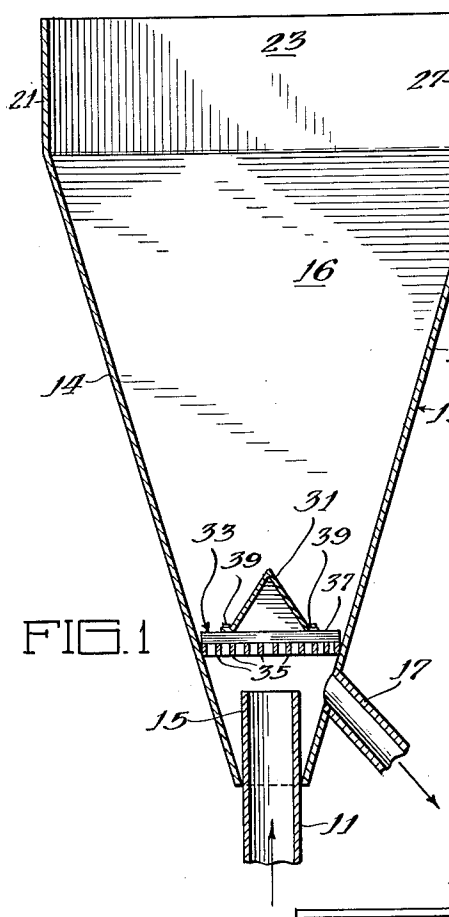


FIG. 1

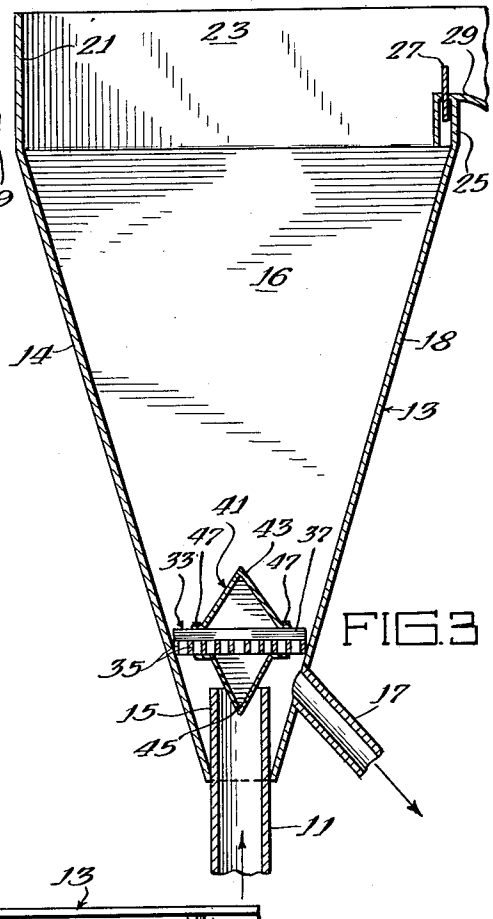


FIG. 3

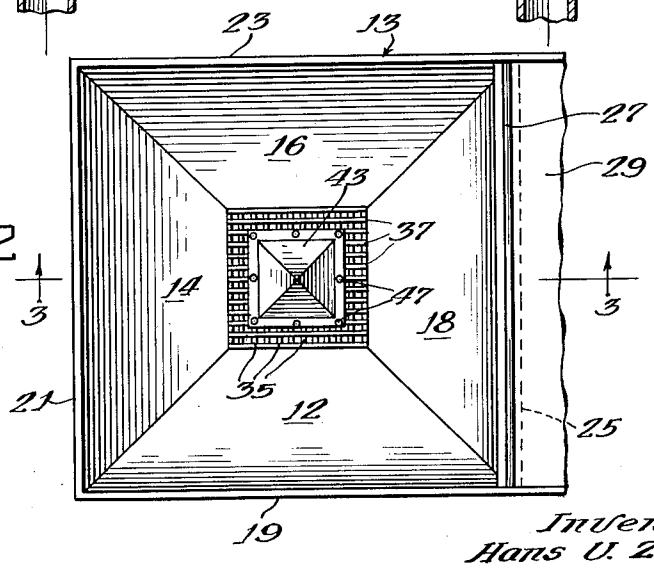


FIG. 2

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FLOTATION APPARATUS

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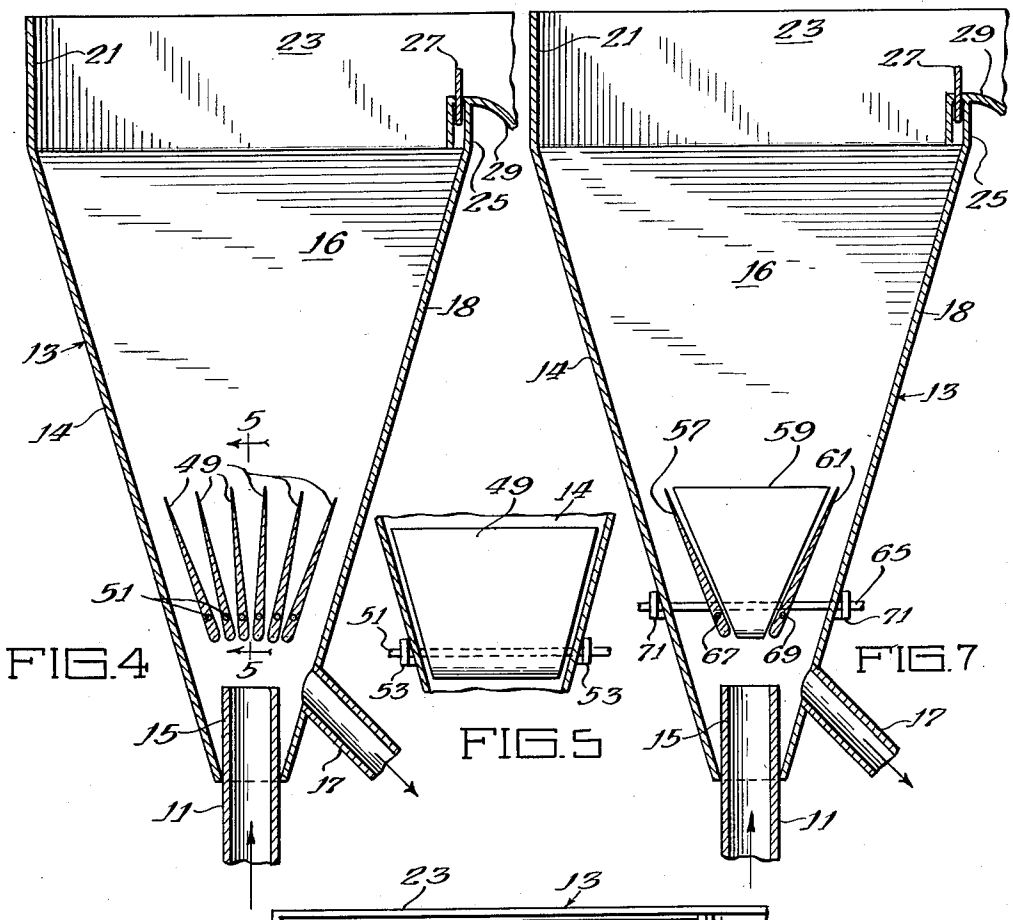


FIG. 4

FIG. 5

FIG. 7

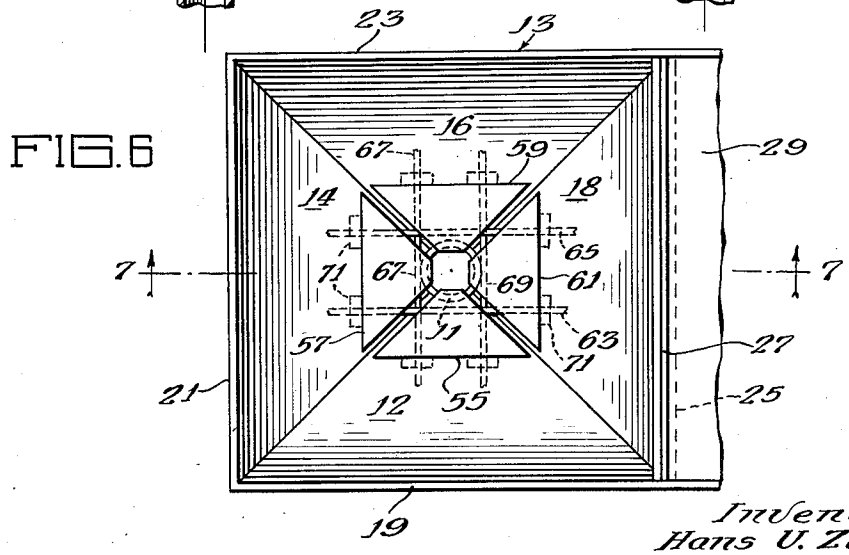


FIG. 6

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FLOTATION APPARATUS

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2 Claims. (Cl. 209—168)

The present invention generally relates to the art of beneficiating materials by flotation techniques, and particularly to the control of flowing streams of liquids in flotation equipment, which streams have ore or other materials suspended or dispersed therein. Generally stated, a principal object of the invention is to provide improved flow control means for flotation equipment.

The beneficiation of minerals by froth-flotation techniques is of great importance in the ore beneficiation art. The flotation process is widely used for treating metallic and non-metallic ores and, in addition, it is receiving an ever widening application in other industries.

In many of the prior art flotation machines the mineral feed, which is usually in the form of an aqueous pulp, is introduced horizontally into a flotation cell which is usually constructed substantially in the form of a cylinder or prism. The pulp is agitated and aerated in the flotation cell by a rapidly rotating impeller which rotates on a substantially vertical axis. The mineral-laden air bubbles separate from the other material and pass upwardly to the pulp level of the flotation cell to form a froth. The froth is then floated off of the top of the cell.

Since the pulp is introduced laterally into a flotation cell, in which the air bubbles are passing chiefly in upward direction, it has been difficult because of this difference in directions of flow to obtain a uniform distribution of air bubbles throughout the cross-section of the cell. It has also been difficult to float mineral particles of relatively large mass in such a flotation cell.

A different type of flotation cell has recently been developed. This new flotation cell is described in detail in copending United States patent application No. 754,765, filed August 13, 1958, now U.S. Patent No. 2,922,521, issued January 26, 1960. The apparatus described in the copending patent application includes an inlet conduit for containing a flowing stream of fluid, and a laterally diverging conduit connected to the inflow conduit at the outflow end thereof for receiving the flowing stream of fluid from the inflow conduit. The laterally diverging conduit comprises a part of the flotation cell. Using this apparatus it has been possible, because of air and pump thrust upwardly into the diverging conduit, to effect a higher weight recovery of materials than can be obtained in more conventional flotation cells; for example, such cells as are used in Fagergren and Denver flotation machines.

A second and more specific object of the invention is to provide improved flow control means for the divergent conduit system of such flotation apparatus.

As will hereinafter appear, the above-stated objects of the invention are accomplished by the provision of flow control means within the diverging conduit system of a flotation cell. The invention makes possible much more positive and much more effective control of the flow streams encountered in diverging conduit flotation cells than has heretofore been attained.

Further objects and advantages of the present invention will be apparent from the following description and accompanying drawings which illustrate several forms of the invention.

In the drawings, wherein are illustrated certain embodiments of the invention:

FIGURE 1 is a sectional view of one form of flotation cell of flotation equipment embodying certain of the features of the invention;

FIGURE 2 is a plan view illustrating another flotation cell embodying certain features in accordance with the present invention;

FIGURE 3 is a sectional view, similar to FIGURE 1, taken on the general line 3—3 of FIGURE 2;

FIGURE 4 is a sectional view, similar to FIGURE 1, illustrating still other features of the invention;

FIGURE 5 is a partial sectional view taken along line 5—5 of FIGURE 4.

FIGURE 6 is a plan view illustrating another flotation cell embodying still other features in accordance with the present invention; and

FIGURE 7 is a sectional view similar to FIGURE 4, taken on the general line 7—7 of FIGURE 6.

The present invention provides an apparatus for froth flotation beneficiation of minerals in a manner that the tailing, or underflow from the flotation cell, contains less of the material which it is desired to float, than heretofore obtainable. The apparatus of the present invention is eminently useful in the beneficiation of potash ores such as sylvinite, langbeinite, mixed ores, etc., phosphate ores, and the like. The apparatus operates efficiently at large throughputs. The apparatus also makes possible the beneficiation of larger ore particles than are usually beneficiated in conventional flotation machines.

In general, the flotation apparatus of the invention comprises an inflow conduit for containing a flowing stream of fluid, a laterally diverging conduit connected to the inflow conduit adjacent to the outflow end thereof for receiving the flowing stream of fluid from the inflow conduit, and at least one flow control member disposed within the diverging conduit to act upon the flowing stream to control the pressure and velocity relationships in the flowing stream. The flow control member preferably establishes a diverging flow pattern downstream of the outflow end of the inflow conduit. It will be understood that the particular structures illustrated in the drawings are merely illustrative embodiments of the general principles involved.

The apparatus provides a flotation cell having a bottom inlet and an overflow adjacent to the upper end of the flotation cell. Between the inlet and overflow, the flotation cell is defined by essentially a rigid walled laterally diverging conduit section. The flotation cells, in accordance with the present invention, illustrated in the drawings, are provided with at least one pyramid or cone or vane disposed between the diverging walls of the flotation cell. The inflow conduit opens centrally or substantially centrally into the flotation cell from below and the pulp-air mixture emerging from the inlet pipe rises in the flotation cell as a jet. The pulp emerging from the inflow conduit flows as a more or less coherent or jet stream and, when no flow control member is present in the cell, as it flows upwardly, the jet stream tends to spread out in the form of a mushroom as the velocity decreases. The air-laden mineral particles continue to rise to the froth level.

Since the jet stream carries the solid entrained particles mainly vertically upwardly, in the same direction that the air bubbles are rising, the adherence of the solid particles to the air bubbles is greatly facilitated and at the same time a shaking or shearing of the solid particles from the bubbles is substantially reduced. For this reason the apparatus enables a reliable flotation of even unusually coarse particles with high efficiency.

It has, however, been observed that when using the apparatus without flow control members for the beneficiation of material having particles larger than the size of the particles normally beneficiated in conventional flotation machines, the tailing or underflow from the flotation cell

is usually of poor quality; that is, the underflow contains mineral components which it is desired to float.

It has now been determined that when the flotation cell is provided with a flow control member in accordance with this invention, a substantial improvement in the operation of the flotation cell is obtained.

A flotation cell employing various forms and arrangements of flow control means within the cell is illustrated in the drawings. The apparatus illustrated in the drawings includes an inflow conduit **11** which is shown connected to the bottom of a rigid-walled, laterally diverging conduit or flotation cell **13**.

The flotation cell **13** is illustrated as an inverted pyramid having a rectangular horizontal cross section; however, the diverging conduit may take on other forms such as an inverted cone. The inflow conduit **11** is also a discharge pipe of a centrifugal pump (not shown). The inflow conduit **11** extends upward and is provided with an extension **15** into the flotation cell **13**. In general, the length of the extension **15** into the flotation cell depends upon the feed rate and the ratio of floated material to non-floated material. For example, when beneficiating different materials, at substantially the same inflow conditions, if the ratio increased from 1:2 to 1:4, the extension **15** is preferably of relatively longer length in the latter operation.

The flotation cell **13** has connected adjacent its lowermost point a pipe **17** through which material may be withdrawn from the flotation cell **13**. The flotation cell is provided at the top with vertical walls **19**, **21**, **23** and **25** which together form a froth box. The upper edge of the wall **25** is somewhat lower than the upper edge of the other walls.

An overflow weir **27** is suitably fixed in wall **25** and is positioned parallel to wall **25** and extends above the upper edge of this wall. The weir **27** is preferably adjustable in height by means not shown. A guide plate **29** is connected to the upper edge of wall **25**, and this guide plate curves downwardly.

The apparatus described hereinabove in detail is also generally described in the hereinbefore referred to co-pending United States application No. 754,765. This co-pending application, however, describes an apparatus which does not include any flow control means between the diverging walls of the flotation cell. The present invention is particularly directed to the flow control means.

Referring now more particularly to FIGURE 1 of the drawings, there is illustrated a flow control means comprising a solid walled pyramid **31** positioned centrally with the flotation cell **13** on a grid **33**. The grid **33** is fabricated of strip steel by overlaying a series of parallel strips **35** with another series of parallel strips **37**, with the lower strips **35** being generally perpendicular to the upper strips **37**. The pyramid **31** is secured to the grid **33** by bolts **39**. Instead of the illustrated pyramid **31**, the flow control member may be embodied as a cone. The lower edges of the lower strips **35** of the grid **33** rest on the diverging walls of the flotation cell **13**. A grid is also positioned within the flotation cell illustrated in FIGURES 2 and 3 and since the grid is substantially the same as the grid illustrated in FIGURE 1, the same numerals, **33**, **35**, and **37**, are used to designate corresponding parts of the grid. The flow control means **41** illustrated in FIGURES 2 and 3 includes a solid walled upright pyramid **43** positioned centrally within the flotation cell **13** on the grid **33** and an inverted solid walled pyramid **45** attached to and depending from the grid. The vertical axis of the pyramids **43** and **45** are substantially in alignment with each other and with the vertical axis of the flotation cell **13** and inlet conduit **11**. The pyramids **43** and **45** are secured to the grid **33** by bolts **47**. The bases of the pyramids are of substantially the same size. Instead of the pyramids illustrated, one of the pyramids may be substituted for by a cone of substantially similar size and shape or both of the pyramids may be substituted for by cones of substantially similar size and shape.

The pyramids illustrated in FIGURES 1, 2, and 3 constitute flow control elements which control and adjust the pressure and velocity relationships existing in the flowing stream passing generally upwardly through the flotation cell **13**. In general, the flow control elements diverge the flowing stream more rapidly than the natural diverging which would occur in the absence of the flow control elements. In other words, the flow control elements control and adjust the velocity of the flowing stream so as to impart to the flowing stream a momentum or horizontal velocity component directed outwardly from the vertical axis of the flotation cell, thereby diverting the stream from its normal path. The magnitude of the force delivered to the flowing stream will, of course, depend upon the angle of inclination of the surface of the pyramid to the normal direction of flow. The flow control element is preferably positioned relatively low in the cell, that is, in a lower portion of the cell, in order that the velocity of the flowing stream may be altered as soon as possible, therefore permitting a large portion of the cell, downstream of the flow control element, to be utilized as a separating zone. The flow control member should, however, not be so low in the cell that it adversely affects the solid particles in the flowing stream themselves.

A flotation apparatus embodying another flow control means in accordance with the general principles of the present invention is illustrated in FIGURES 4 and 5. This structure includes a plurality of guide vanes **49** symmetrically spaced and arranged across the lower section of the flotation cell **13**. The guide vanes may be straight or may be curved (not illustrated). The leading edges of the vanes are rounded and the trailing end portions are tapered as indicated. The guide vanes are of a number and of a length sufficient to diverge the flowing stream to the degree desired.

As illustrated in FIGURE 5, each of the guide vanes extend substantially from wall to wall of the flotation cell.

Each of the guide vanes **49** is fixedly mounted at a lower portion thereof on a spindle **51** which extends through the walls of the flotation cell **13**. Suitable packing seals **53** are provided around the spindles in order to prevent fluid from leaking out of the flotation cell.

The vanes **49** divide the stream of fluid issuing out of the inflow conduit **11** into a plurality of segments. The angle of inclination which the vanes **49** make with the normal direction of flow may be adjusted by rotating the spindles **51** until the desired predetermined angle is achieved and the vanes may then be fixed in this position. Any suitable means (not illustrated) may be used to adjust the angle and fix the vanes in position.

A flotation cell embodying another flow control means in accordance with the general principles of the present invention is illustrated in FIGURES 6 and 7. This structure includes four guide vanes **55**, **57**, **59**, and **61**. The guide vanes **55** and **59** are fixedly mounted on parallel spindles **63** and **65** respectively and the guide vanes **57** and **61** are similarly fixedly mounted on parallel spindles **67** and **69**. Spindles **63** and **65** are, however, substantially perpendicular to spindles **67** and **69**. The lower edges of the guide vanes terminate in substantially the same plane. In cross section, the vanes have leading edges which are rounded and the trailing end portions are tapered as indicated. The vanes have a narrow dimension (measured parallel to the respective spindle on which it is mounted) at the lower edges and widen toward the upper edges as indicated. The spindles extend through the walls of the flotation cell and suitable packing seals **71** are provided around the spindles in order to prevent fluid from leaking out of the flotation cell. These spindles are adjustable to predetermined positions by means not illustrated, similar to spindles **51** so as to

adjust the vanes 55, 57, 59 and 61 to predetermined positions. In general, the vanes are adjusted so that the angles between each of the vanes and the vertical axis of the flotation cell are substantially equal.

Various flow control means in accordance with this invention have been illustrated and described with specific reference to certain construction details; however, it is to be understood that such details are illustrative only and not by way of limitation. Other modifications and equivalents will be apparent to those skilled in the art from the foregoing description.

A pilot plant size flotation cell was constructed in accordance with the embodiments described and illustrated in FIGURES 1, 2, and 3. This flotation cell was used in a series of tests. In all of the tests, the feed was an aqueous pulp of a fatty acid reagentized phosphate rock containing a major proportion of −14 +35 mesh size particles with the minor proportion predominantly −35 +150 mesh. As is known to those skilled in the art of beneficiating minerals by flotation, the −14 +35 material is usually considered too coarse for efficient separation in conventional flotation equipment. All conditions were maintained substantially identical except as noted.

Test 1

The flotation cell was used without any flow control means within the cell. The results were as follows:

Product	Wt., Percent	BPL, Percent	Recovery, Percent
Concentrate	51.2	71.67	80
Tailings	48.1	19.00	20
Total	100.0	46.08	100.0

Test 2

The flotation cell was provided with a grate (no pyramid) substantially like the grate illustrated in FIGURE 1. The results were as follows:

Product	Wt., Percent	BPL, Percent	Recovery, Percent
Concentrate	49.0	70.04	84.0
Tailings	51.0	12.89	16.0
Total	100.0	40.96	100.0

Test 3

The flotation cell was provided with an upright pyramid on the grate, substantially as illustrated in FIGURE 1. The results were as follows:

Product	Wt., Percent	BPL, Percent	Recovery, Percent
Concentrate	51.8	69.16	88.2
Tailings	48.2	7.98	11.8
Total	100.0	40.72	100.0

Test 4

Test 3 was repeated to check the results. The results were as follows:

Product	Wt., Percent	BPL, Percent	Recovery, Percent
Concentrate	50.3	60.72	87.0
Tailings	49.7	10.49	13.0
Total	100.0	39.81	100.0

Test 5

The flotation cell was provided with two pyramids substantially as illustrated in FIGURES 2 and 3. The results were as follows:

Product	Wt., Percent	BPL, Percent	Recovery, Percent
Concentrate	50.7	64.57	93.5
Tailings	49.3	4.67	6.5
Total	100.0	35.13	100.0

The above tests illustrate the benefits obtainable when using flow control means in accordance with this invention.

Having now fully described and illustrated the invention, what is desired to be secured and claimed by Letters Patent is set forth in the appended claims.

I claim:

1. Flotation apparatus comprising in combination a substantially vertical inflow conduit for containing a flowing stream of a mineral feed in the form of an aqueous pulp, an upwardly extending laterally diverging conduit of rectangular horizontal cross section having a substantially vertical axis in substantial alignment with the vertical axis of said inflow conduit and having a bottom inlet connected to said inflow conduit adjacent the outflow end thereof, a froth box at the upper portion of said diverging conduit for receiving material from said diverging conduit, and an inverted solid walled pyramid disposed within said diverging conduit in a lower portion thereof and a solid walled upright pyramid disposed within said diverging conduit above said inverted pyramid and adjacent the lower end of said diverging conduit, said pyramids having substantially vertical axes in substantial alignment with the vertical axis of the inflow conduit, said pyramids acting upon the flowing stream to establish a diverging flow pattern within said diverging conduit downstream of the outflow end of the inflow conduit and control the pressure and velocity relationships in the flowing stream.

2. Flotation apparatus comprising in combination a substantially vertical inflow conduit for containing a flowing stream of a mineral feed in the form of an aqueous pulp, an upwardly extending laterally diverging conduit of rectangular horizontal cross section having a substantially vertical axis in substantial alignment with the vertical axis of said inflow conduit and having a bottom inlet connected to said inflow conduit adjacent the outflow end thereof, a froth box at the upper portion of said diverging conduit for receiving material from said diverging conduit, and an inverted solid walled pyramid having a substantially vertical axis in substantial alignment with the vertical axis of said inflow conduit disposed within said diverging conduit in a lower portion thereof to act upon the flowing stream to establish a diverging flow pattern within said diverging conduit downstream of the outflow end of the inflow conduit and control the pressure and velocity relationships in the flowing stream, a grid extending across the area of said diverging conduit with said inverted pyramid mounted thereon, and an upright pyramid supported on said grid above said inverted pyramid with the vertical axis of said pyramids in substantial alignment with the vertical axis of said inflow conduit.

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