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C. E. WALKER ET AL

3,288,285

AIR CLASSIFIER

Filed July 9, 1963

4 Sheets-Sheet 1

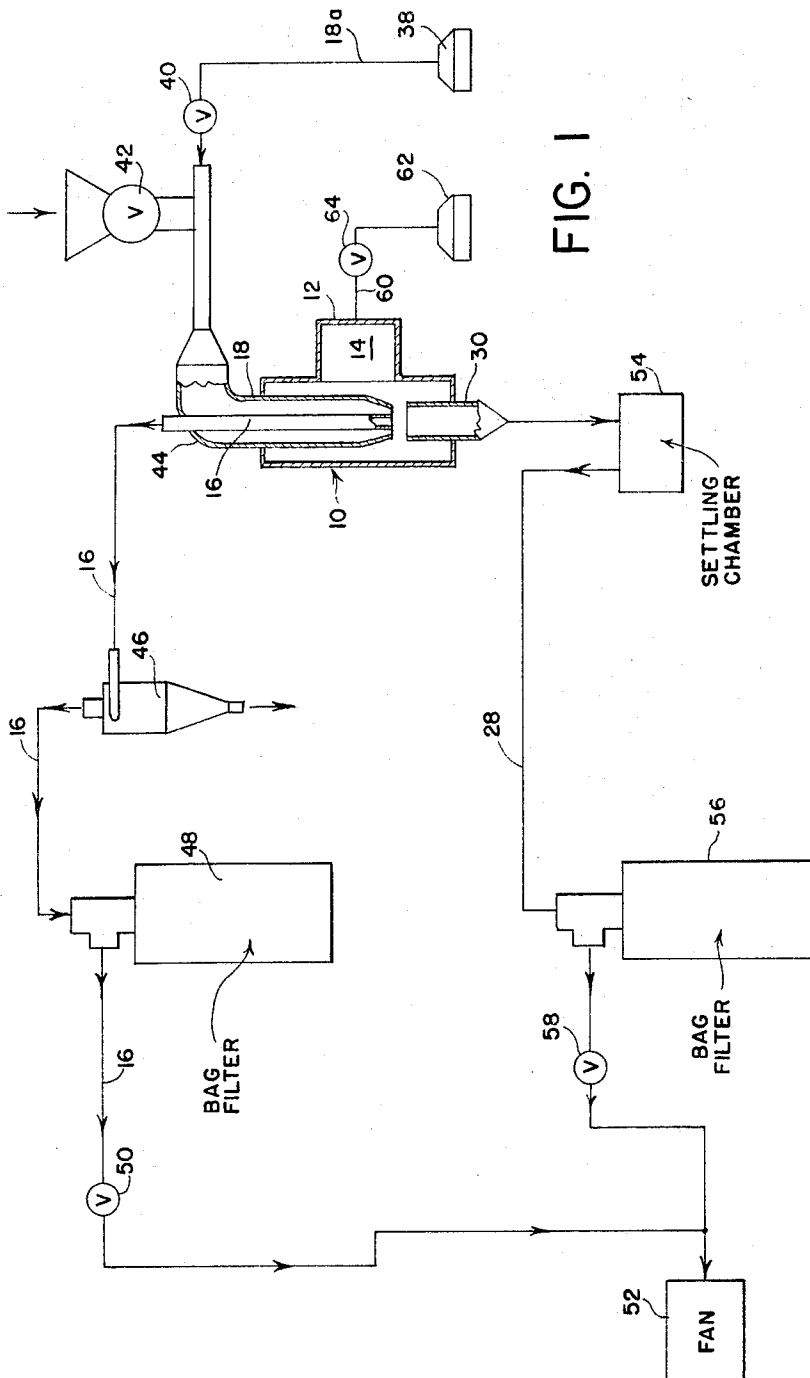


FIG. 1

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FIG. 3

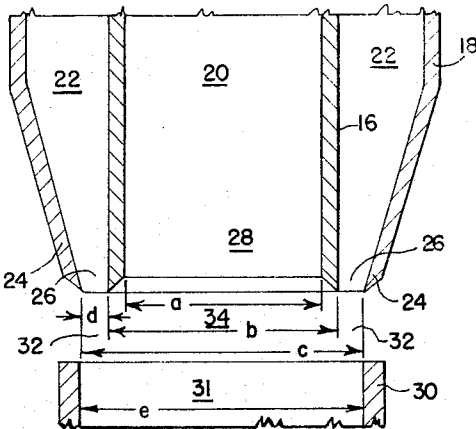
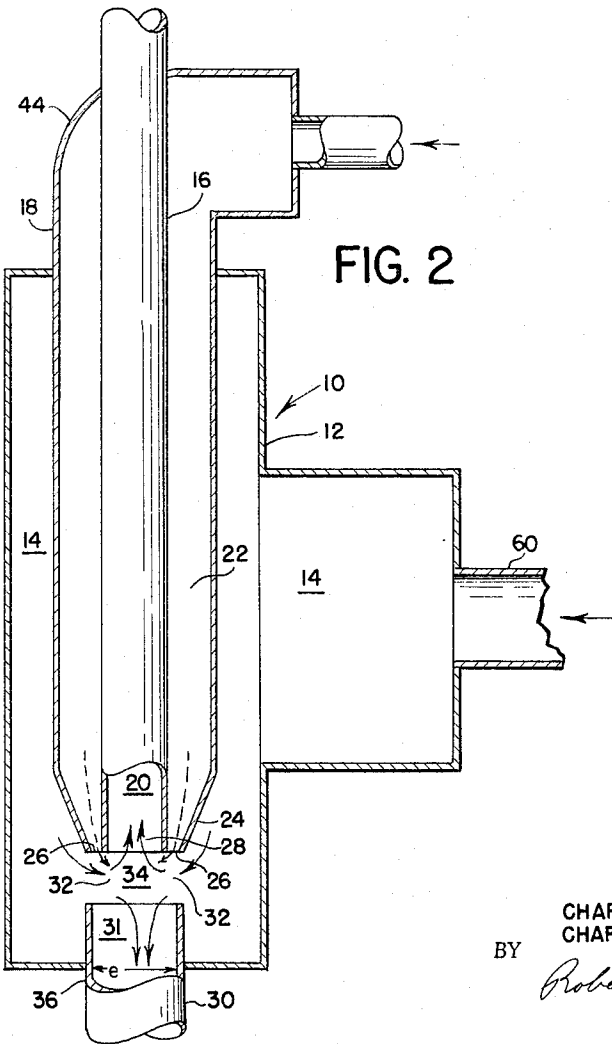


FIG. 2



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FIG. 4

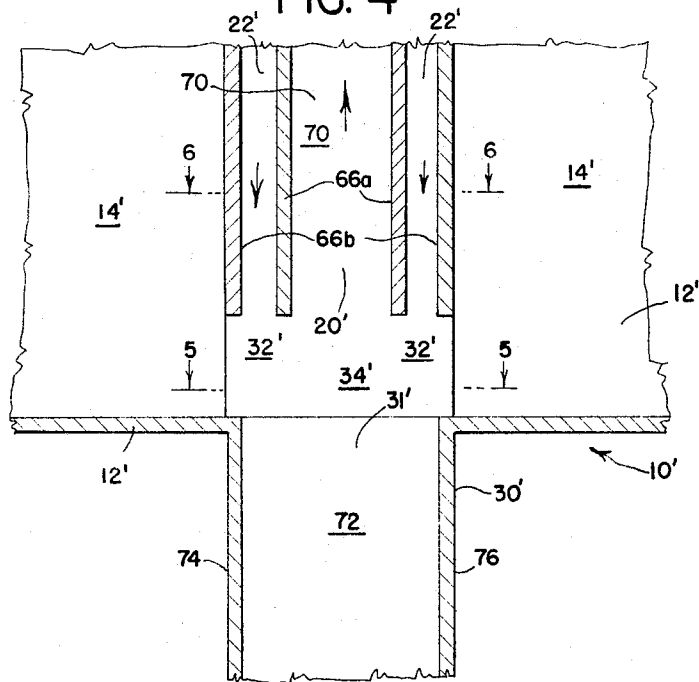


FIG. 5

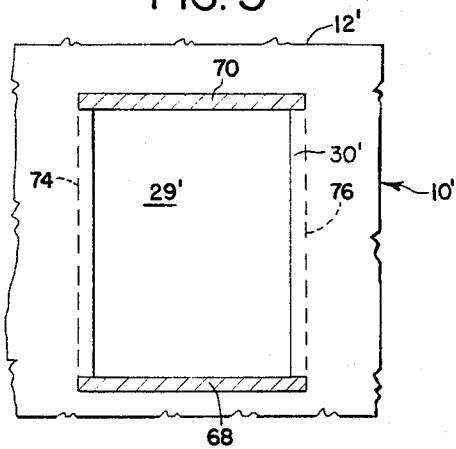
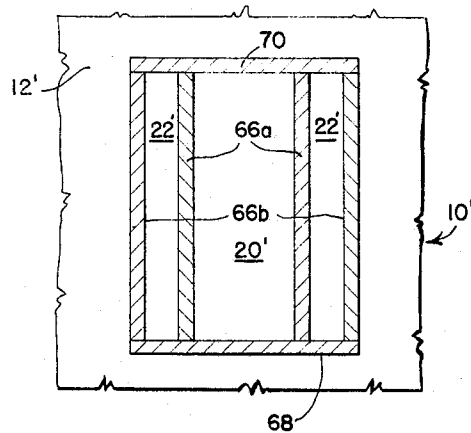


FIG. 6



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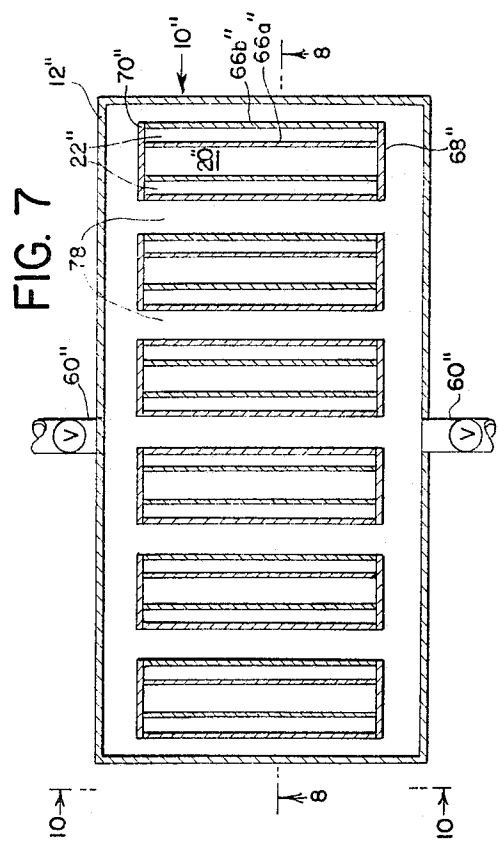
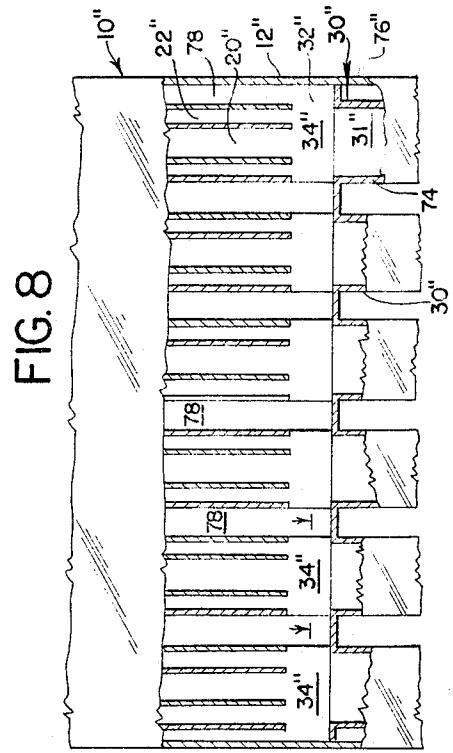
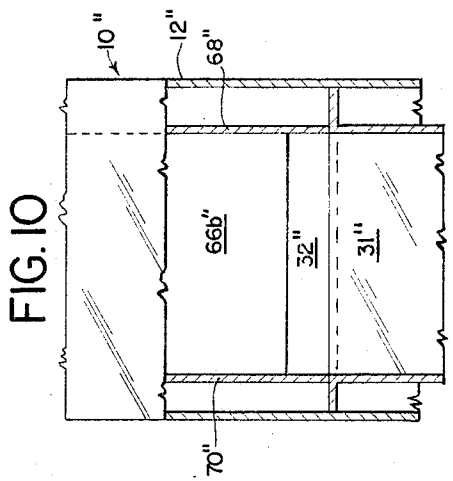
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15 Claims. (Cl. 209-143)

This invention relates to the classification of finely ground or powdered material into fractions of different particle size, and more particularly to a method and apparatus of accomplishing "in-line" air classifying of material such as flour.

It is generally known in the flour milling art that the average size of the protein particles of the flour as compared with that of the starch and whole endosperm particles of the flour is quite small. As a result, there has been considerable interest in classifying the flour according to particle size as a means of separating fractions containing different amounts of protein. This process of enriching one fraction at the expense of the other is difficult to practice on a commercial scale with classifying apparatus employing sifting screens and the like, because of the fineness of the particles which are to be separated out as the protein enriched fraction (i.e. about 15 microns or less in diameter). Hence efforts have been directed to air classification as a means of obtaining separation of the very fine flour particles. Although prior art mechanisms have been developed to accomplish such air classification on a commercial scale, further efforts have been directed to devising simplified apparatus which is relatively inexpensive and readily adaptable to many types of plant installations.

Accordingly, it is an object of the present invention to provide an improved "in-line" air classifier, which, in a flour milling operation, is capable of separating a desired protein enriched fraction; which is simple, economical, and compact; and which can readily be made a part of many existing flour milling installations.

It is also an object to provide an improved process for such "in-line" air classification of particles such as flour.

It is a further object to provide such a process and apparatus wherein the separation can be made with a high degree of "efficiency" and with a low "cut-point," and wherein the "cut-point" can easily be shifted within reasonable limits to obtain a greater or less percentage of the material being classified as the protein enriched fraction.

With respect to this last-name object, it should be indicated that "cut-point" is defined as that diameter in the cumulative particle size distribution at which particles have an equal probability of being in the course or fine fractions. Of all particles of a larger diameter, more than 50% are in the course fraction, whereas of all particles of a smaller diameter, more than 50% are in the fine fractions. How much overlap there is, is indicated by the "efficiency" of the classification. The "efficiency" is a quantitative measure of the freedom of a fraction from contamination by particles of the other fraction. "Sharpness index (S.I.)" is a numerical measure of efficiency, sometimes used in the flour milling industry. An S.I. of zero indicates no classification and one of infinity indicates a perfect separation with no overlap. An S.I. of 6 to 10 represents a very good split, and usually covers the range of the desired classification.

These and other objects and features of the invention will be more readily understood and appreciated from the following detailed description of the preferred embodiments thereof selected for purposes of illustration and shown in the accompanying drawings, in which,

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FIGURE 1 is a schematic drawing illustrating an apparatus embodying preferred teachings of my invention,

FIGURE 2 is a side elevational view, taken partly in section, of the air classifying device illustrated in FIG. 1,

FIGURE 3 is a view similar to FIG. 2, detailing that portion of the device proximate the classifying area thereof,

FIGURE 4 is a view taken in vertical section illustrating a second embodiment of my invention,

FIGURE 5 is a plan sectional view taken on line 5-5 of FIG. 4,

FIGURE 6 is a plan sectional view taken on line 6-6 of FIG. 5,

FIGURE 7 is a plan sectional view of yet a third embodiment of my invention,

FIGURE 8 is a side elevational view of the apparatus of FIG. 7 and taken partly in sections along line 8-8 of FIG. 7,

FIGURE 9 is a plan sectional view taken on line 9-9 of FIG. 8, and

FIGURE 10 is a partial sectional view taken generally on line 10-10 of FIG. 7.

In the FIGS. 1-3, there is shown an air classifying unit, generally designated 10, which comprises a housing 12 defining a substantially closed chamber 14. Extending downwardly through the upper end of the housing 12 and into the chamber 14 are an inner and outer cylindrical conduit 16 and 18, respectively, arranged concentrically with respect to another so as to define an inner cylindrical passage 20 surrounded by an outer annular passage 22. The lower end 24 of the outer conduit 18 tapers inwardly to a moderate extent to terminate in the same horizontal plane as does the inner conduit 16, to define therewith a convergent annular discharge opening 26, while the lower end of the inner conduit 16 defines a circular intake opening 28.

Extending upwardly through the lower end of the housing 12 and into the chamber 14 is a third cylindrical conduit 30, which is axially aligned with the upper conduits 16 and 18 and defines a flow passage 31. The conduit 30 has a diameter equal to that of the lower end 24 of the conduit 18 and terminates a moderate distance therebelow so as to define with this conduit portion 24 a generally cylindrical gap or opening 32 through which the housing chamber 14 communicates with each of the conduits 16, 18 and 30.

To indicate generally the mode of operation of this unit 10, the flour material to be classified is fed into the aforementioned outer conduit 18 to be pneumatically conveyed through the annular passage 22 to be discharged at a relatively high velocity out the convergent annular opening 26. This air stream carrying the flour material to be classified is called the "primary" air stream; hence the conduit 18, annular passage 22 and annular opening 26 are referred to, respectively, as the "primary conduit," the "primary air passage" and the "primary discharge opening." This space between the upper conduits 16 and 18 and the lower conduit 30, which space is surrounded by the cylindrical opening 32, is the area in which this flour material being discharged from the annular opening 26 is separated into a fine and a course fraction, this area 34 thus being called the "classifying area" or the "separation area." The fine fraction of material passes from the separation area out the passage 20 defined by the inner conduit 16, and the course fraction travels out the passage 31 defined by the lower conduit 30. Hence, these conduits 16 and 30 are referred to, respectively, as the "fine fraction conduit" and the "coarse fraction conduit," and the related passages 20 and 31 are similarly designated.

The manner in which the unit 10 cooperates as part of an air classifying system is illustrated schematically in FIG. 1, wherein it can be seen that air is drawn through a suitable filter 38 into an initial portion 18a of primary conduit 18, the flow through which is controlled by a suitable valve 40. Downstream of this control valve 40 the flour material to be classified is fed into the primary conduit 18 by means of a suitable feed mechanism, shown schematically at 42. A short distance upstream of the point at which the conduit 18 enters into the housing 12, this conduit 18 (to accommodate the inner conduit 16) expands in cross sectional area and describes an elbow bend, as at 44. At this elbow 44 the inner conduit 16 projects into the primary conduit 18 to define the afore-described primary annular passage 22 through which the pneumatically conveyed flour in primary conduit 18 is moved into the classifying unit 10.

The inner or fine fraction conduit 16 extends from the housing 12 and out the elbow 44 of the conduit 18 and leads to a cyclone separator 46 and thence to a bag filter 48, to remove the fine fraction of flour material entrained in the air stream flowing in the conduit 16 from the unit 10. From the bag filter 48, the conduit 16 then leads through a flow control valve 50 to be discharged through a fan 52. The lower or coarse fraction conduit 30 leads to a settling chamber 54, then to a respective bag filter 56, which members 54 and 56 remove the coarse fraction of flour material entrained in the coarse fraction air stream, and then through a control valve 58 to the fan 52. Thus it can be seen that by manipulating the valves 50 and 58 the relative flow of air out the coarse fraction conduit 30 and out the fine fraction conduit 16 can easily be controlled.

Leading into the chamber 14 defined by the housing 12, is a conduit 60 (called a "secondary air" conduit) having a related filter 62 and control valve 64. When the fan 52 draws air through the primary conduit 18 into the separation area 34 and thence to the conduits 16 and 30, air is also drawn through the secondary conduit 60, into the chamber 14, through the cylindrical gap or opening 32 and into the separation area 34.

To obtain a separation of relatively high sharpness index and low cut-point, the four control valves 40, 50, 58, and 64 are so arranged that the volumetric rate of air flow out the inner or fine fraction conduit 16 is moderately larger than that into the classifying unit 10 from the primary conduit 18. Since the total flow into the classifying unit 10 must equal the total out-flow, the volumetric rate at which air flows through the secondary line 60 into the secondary air opening 32 is moderately greater than the volumetric air flow out the coarse fraction conduit 30. The result is that substantially all the air from the primary conduit 18 flows out the primary discharge opening 26 and describes an approximate 180° curve through the separation area 34 to flow into the fine fraction conduit 16. Since the volume of flow into the fine fraction conduit 16 is moderately greater than that through the annular opening 26, a portion of the secondary air flowing through the opening 32 moves along a path through the separation area 34 into the fine fraction conduit 16, while the remainder of the secondary air flows through the separation area 34 and out the coarse fraction conduit 30. The smaller particles of the flour material flowing out the annular discharge opening 26 are retained in the air flowing into the fine fraction conduit 16 (which is substantially all the primary air and a portion of the secondary air), while the larger particles pass from the primary air stream, through that portion of secondary air flowing into the conduit 16, and into the coarse fraction conduit 30.

By constructing this classifying unit 10 according to the following specified dimensions, a separation having a relatively low cut-point and a high efficiency can be attained under the above-described operating conditions. The inside and outside diameter (designated a and b respectively in FIG. 3) of the fine fraction conduit 16, are re-

spectively, $\frac{3}{4}$ " and $\frac{7}{8}$ ". The inside diameter (designated c in FIGURE 3) of the outside or primary conduit 18 at its lower end 24 is $1\frac{1}{16}$ ", so that the width (designated d in FIG. 2) of the annular discharge opening 26 is $\frac{3}{32}$ ". The inside diameter (designated e in FIG. 2) of the coarse fraction conduit 30 is the same as that of the lower end 24 of the conduit 18 (i.e. $1\frac{1}{16}$ "). The distance between conduits 18 and 30 (i.e. the width of the gap or opening 32 through which the secondary air enters the separation area 34) is determined in relation to the amount of secondary air which is desired to flow into the fine fraction and coarse fraction conduits 16 and 30.

Recommended conditions for producing a 20% protein fine fraction from wheat flour stock are as follows (with the designated velocities being those taken proximate the separation area 34):

(1) Primary air velocity between 100 and 200 ft./sec.,

(2) Air velocity out the fine fraction conduit less than the primary air velocity (determined by geometric and material balance);

(3) Secondary velocity $\frac{1}{4}$ to $\frac{1}{2}$ primary air velocity; and

(4) Air velocity out the coarse fraction conduit between 10 to 25 feet per second.

By regulating the valves 40, 50, 58 and 64 so as to vary the respective air flows therethrough, both the cut-point and sharpness index can be changed to a desired level. For example to decrease the percent of fines and reduce their average size, the following changes in operating conditions may be used:

(1) Increase primary air velocity;

(2) Reduce secondary air velocity;

(3) Increase coarse air velocity;

(4) Decrease fine air velocity.

A second embodiment of the present invention is illustrated in FIGS. 4-6, wherein there is a classifying unit 10', having a housing 12' defining a chamber 14'. There are provided four vertical parallel plates designated 66a and b which reach between and are perpendicular to front and rear walls 68 and 70 located in the housing 12'. The two center plates 66a (with the walls 68 and 70) define a middle fine fraction air passage 20', while each outer plate 66b with its related proximate inner plate 66a and the walls 68 and 70 defines a related one of two branch portions 22' of the primary air passage. The width (dimension taken perpendicular to the plates 66a and b) of each branch 22' of the primary passage should be about $\frac{1}{10}$ of an inch, while the width of the fine fraction passage 20' should be about $\frac{3}{8}$ of an inch. The dimensions of these passages 20' and 22', measured between the walls 68 and 70 may be as long as desired, depending upon the rate at which flour material is to be classified by the unit, but should be substantially greater than the width dimension.

The coarse fraction conduit 30' defining a passage 31' extends from the lower portion of the housing 12' and has a generally rectangular cross sectional configuration to correspond with the general rectangle defined by the outer plates 66b and the front and rear walls 68 and 70. These walls 68 and 70 are coplanar with and join to the front and rear walls (the rear wall being designated 72) of the coarse fraction conduit 30', so that the outer plates 66b define with the side walls 74 and 76 of the coarse fraction conduit 30' a pair of secondary air openings 32'.

Although not shown herein, it is to be understood that suitable apparatus is provided (as shown in FIG. 1 in the first embodiment) to feed the primary air stream carrying the flour material to be classified into passage 22', and to provide flow of secondary air into the unit 10'. Also conduits are provided to carry the fine and coarse fractions from the unit 10' through, respectively, the passages 20' and 31'.

In operation, flour material to be classified is pneumatically conveyed through the primary air passage

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branches 22' into the separation area 34' (that space between the plates 66a and b and the conduit 30') with the fine fraction passing out the passage 20' and the coarse fraction out the conduit 30'. Secondary air is provided in a manner similar to the previous embodiment, i.e. through a valve controlled intake opening (not shown) in the housing 12' and through the gap 32' between the plates 66b and the coarse air conduit 30'.

In FIGS. 7-10 there is shown a third embodiment, wherein it can be seen that for a larger operation, several sets of four plates (i.e. 66a'' and 66b'') (each set having a related coarse air conduit 30'') can be provided in one unit. Since the various components of this third embodiment are quite similar to those shown in the second embodiment of FIGS. 4-6, like numerical designations will be given, with a double prime (") distinguishing those of the third embodiment, and a detailed description of these components of the third embodiment will accordingly be omitted. Each such set of plates 66a'' and 66b'' is spaced from its proximate set of plates 66a'' and 66b'' in a direction perpendicular to the respective planes occupied by the plates 66a'' and b'' so that secondary air can flow into the areas 78 between proximate sets of plates 66a'' and b'' and into the separation area 34'' of each set. The mode of operation is substantially the same as in the previous two embodiments, it being understood that suitable apparatus is utilized as in the first embodiment to provide primary and secondary air flow (secondary conduits being shown at 60'') into the unit 10'' and to provide fine and coarse fraction flow from the unit 10''. The material to be classified flows into the separation areas 34'' through the primary passages 22'', with the fine fraction passing out passages 20'' and the coarse fraction out passages 30''. Secondary air flows through the conduits 60'' and the areas 78, and then through the various gaps 32'' into the related separation areas 34''.

What is claimed:

1. An apparatus to classify by use of a fluid medium finely divided material such as flour into a coarse and a fine fraction, said classifier including a chamber having a separation area therein, a primary conduit arranged to pneumatically convey material to be classified and leading in a first predetermined direction to said separation area, a fine fraction conduit leading from said separation area along a second predetermined direction, means for positioning said primary conduit and said fine fraction conduit relative to each other so that a first flow path is defined passing from said primary conduit through said separation area into said fine fraction conduit, said first flow path being caused to bend in said separation area in a predetermined direction of bend and with a predetermined degree of curvature as it passes from said primary conduit to the fine fraction conduit, a coarse fraction conduit leading from said separation area, means for positioning said coarse fraction conduit relative to said primary conduit so that a second flow path is defined passing through said separation area from the primary conduit to said coarse fraction conduit, said second flow path having a degree of curvature less than said first flow path, secondary inlet means leading to said separation area, means for positioning said secondary inlet means and said fine fraction conduit relative to each other so that a third flow path is defined passing through said second flow path, fluid actuating and control means to cause pressure differentials in said apparatus so that said fluid medium flows from said primary conduit and said secondary air inlet means into said separation area and said fluid medium flows from said separation area into said fine fraction conduit and into said coarse fraction conduit, said fluid actuating and control means being capable of being so arranged that the rate of fluid flow from said secondary inlet means is greater than the rate of fluid flow out said coarse fraction conduit, whereby a portion of the fluid from said secondary inlet means flows into said fine fraction conduit and another

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portion thereof flows into the coarse fraction conduit, and substantially all of the fluid from said primary conduit flows into said fine fraction conduit, with the result that a fine fraction of said material is carried into said separation area from said primary conduit and is entrained in fluid flowing in said first flow path and in said third flow path, and a coarse fraction of said material moves along said second flow path to pass through said third flow path, and into said coarse fraction conduit.

2. The apparatus as recited in claim 1 wherein said primary conduit means and said coarse fraction conduit means are substantially aligned so that said second flow path is in a generally straight line, and said fine fraction conduit being so arranged that said first flow path has a degree of curvature greater than 90 degrees.

3. The apparatus as recited in claim 1, wherein said coarse fraction conduit means and said fine fraction conduit means are oppositely positioned with respect to said separation area so as to extend oppositely therefrom, said primary conduit means being adjacent to, and on each side of, said fine fraction conduit means and being substantially aligned with said coarse fraction conduit means, so that air flow along said first flow path converges in said separation area from two side portions of said first flow path while flowing into said fine fraction conduit means, said secondary inlet means being adjacent both said side portions of said first flow path.

4. An in-line classifying apparatus for finely divided material such as flour, said apparatus comprising a classifying unit defining a classifying area, a primary conduit formed by first wall means to carry material to be classified and leading into said classifying area, a coarse fraction conduit formed by second wall means, and a fine fraction conduit also formed by said first wall means, said coarse and fine fraction conduits leading from said classifying area, a secondary air opening means leading to said classifying area, fan means to cause a pressure differential to move air from said primary air conduit and said secondary air opening into said area and to move air from said area into said coarse fraction and fine fraction conduits, valve means to control the flow in each of said conduits and through said secondary opening means, said primary conduit wall means defining a primary discharge opening having a relatively small width and a length substantially greater than its width, said wall means also defining an intake opening for said fine fraction conduit, said fine fraction intake opening having a width substantially greater than the width of said primary opening with said primary opening extending about substantially the entire perimeter of said fine fraction intake opening and facing in the same direction as said intake opening so that a first flow path passing from said primary discharge opening to said fine fraction intake opening curves approximately 180 degrees through said classifying area, said coarse fraction conduit wall means defining a coarse fraction intake opening which faces toward both said primary discharge opening and said fine fraction intake opening, so that a second flow path passing from said primary opening to said coarse fraction intake opening has at most a small degree of curvature relative to said first flow path, said first wall means being spaced from said second wall means so as to define said secondary opening means which is adjacent to said coarse fraction intake opening and said primary outlet opening but spaced from said fine fraction intake opening.

5. The apparatus as recited in claim 4, wherein said classifying unit has a housing enclosing said classifying area and both of said wall means, said housing having inlet means by which air flow through said secondary opening is controlled.

6. The apparatus as recited in claim 4, wherein said first wall means comprises an inner wall which closes on itself to define said fine fraction intake and an outer wall enclosing said inner wall and spaced radially therefrom so as to define a generally annular primary outlet opening.

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7. The apparatus as recited in claim 6, wherein said inner and outer walls are shaped to form a convergent primary outlet opening.

8. The apparatus as recited in claim 6, wherein the width of said primary opening is between $\frac{1}{5}$ to $\frac{1}{10}$ of the diameter of said fine fraction intake opening.

9. The apparatus as recited in claim 8, wherein said coarse fraction intake opening has a diameter of substantially the same dimension as the diameter of said outer wall.

10. The apparatus as recited in claim 4, wherein said wall means comprises a pair of generally parallel spaced inner walls defining said fine fraction intake opening and a pair of outer walls enclosing said inner walls and spaced outwardly therefrom and parallel thereto to define two elongated portions of said primary air opening, said portions being on opposite sides of said fine fraction intake opening, said other walls means comprising a third pair of walls substantially co-planar with said outer walls.

11. The apparatus as recited in claim 10, wherein said pairs of inner, outer and third walls comprises a classifying unit portion, and there are a plurality of such classifying unit portions which are spaced from one another in a direction generally perpendicular to said walls, whereby the space between a pair of said unit portions provides a secondary air passage leading to said secondary openings of a related proximate pair of said unit portions.

12. A process for the in-line classification of material such as flour, comprising:

- (a) feeding in a first direction into a separation area at a predetermined speed by means of suitable air actuating and containing means, a primary stream of air which is pneumatically conveying material to be classified,
- (b) directing by said actuating and containing means said primary air stream from said separation area along a second direction, said second direction making an angle with said first direction so that said primary air stream curves at least 90 degrees through said separation area,
- (c) directing by said actuating and containing means a stream of secondary air into said separation area, and directing a first portion of said secondary air along said second direction with the primary air stream from said separation area, said first portion of secondary air traveling a path spaced radially outward from the curve described by said primary air stream through said separation area,

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(d) directing a second portion of said secondary air stream from said separation area along a third direction substantially aligned with said first direction, whereby that fraction of said material carried into said separation area by said primary air stream which, because of its inertia, passes out of said primary air stream and through said first portion of said secondary air stream, is carried from said separation area by said second portion of said secondary air stream, and

(e) individually controlling the relative velocities of the streams of air as they flow in the first, second, and third directions.

13. The process as recited in claim 12, wherein said actuating and confining means is so arranged that the speed of said secondary air stream is between approximately $\frac{1}{4}$ to $\frac{1}{2}$ the speed of said primary air stream.

14. The process as recited in claim 12, wherein said actuating and confining means is so arranged that the speed of said secondary air stream portion traveling in said third direction is between approximately $\frac{1}{20}$ to $\frac{1}{4}$ of the speed of said primary air stream.

15. The process as recited in claim 12, wherein:

- (a) the velocity of said primary stream traveling in said first direction is between approximately 100 to 200 feet per second.
- (b) the velocity of air traveling in said second direction is moderately less than air traveling in said first direction,
- (c) the velocity of the first portion of said secondary air is approximately $\frac{1}{4}$ to $\frac{1}{2}$ the velocity of the primary stream traveling in the first direction, and
- (d) the velocity of the second portion of the secondary air flowing in said third direction is between approximately 10-25 feet per second,
- (e) said velocities being taken at a point proximate the separation area.

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