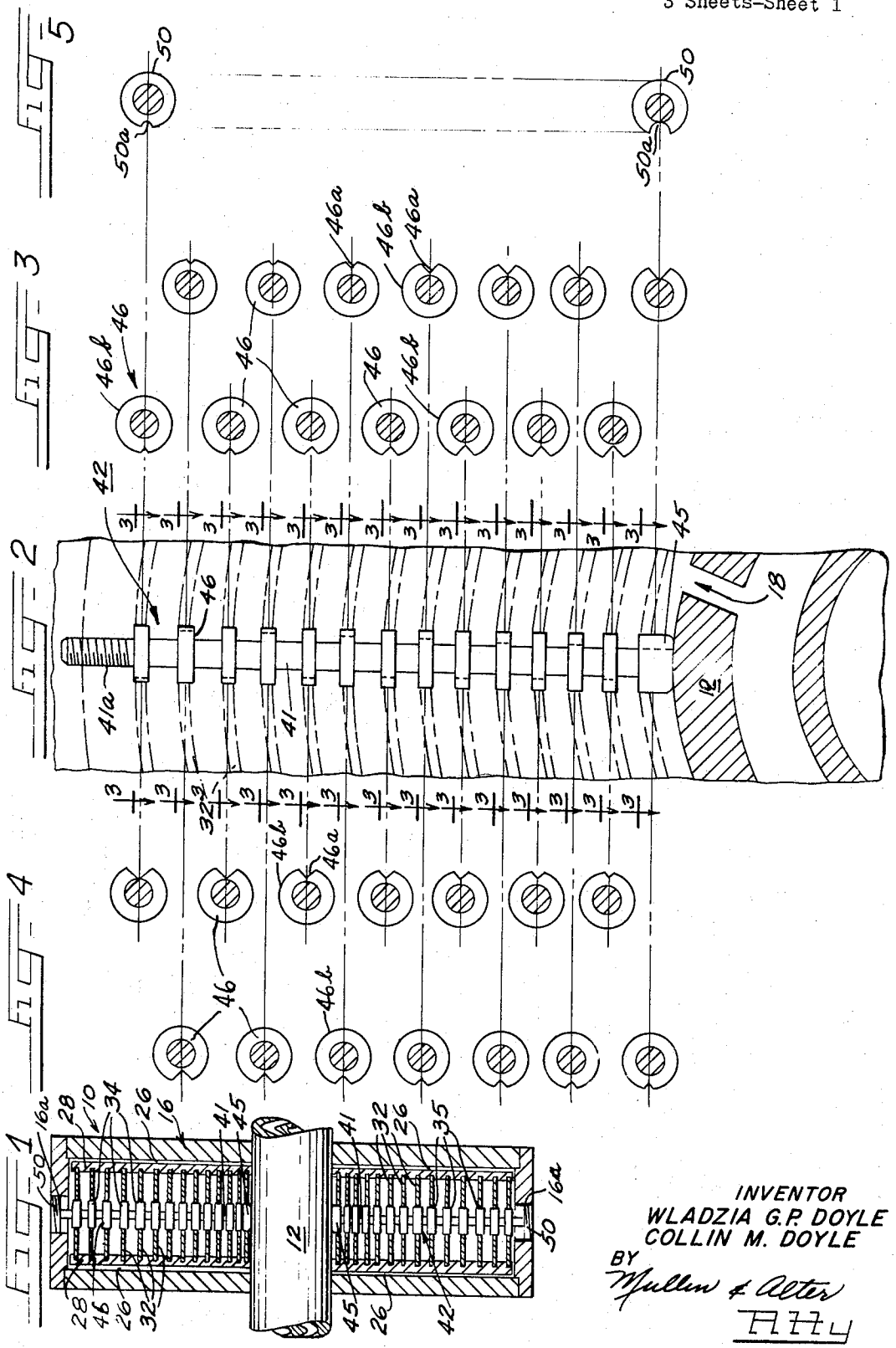
Oct. 31, 1967 W. G. P. DOYLE ET AL 3,350,000

INTEGRAL GRADIENT REMOVABLE DISC COLUMNS

Filed May 7, 1965 3 Sheets-Sheet 1

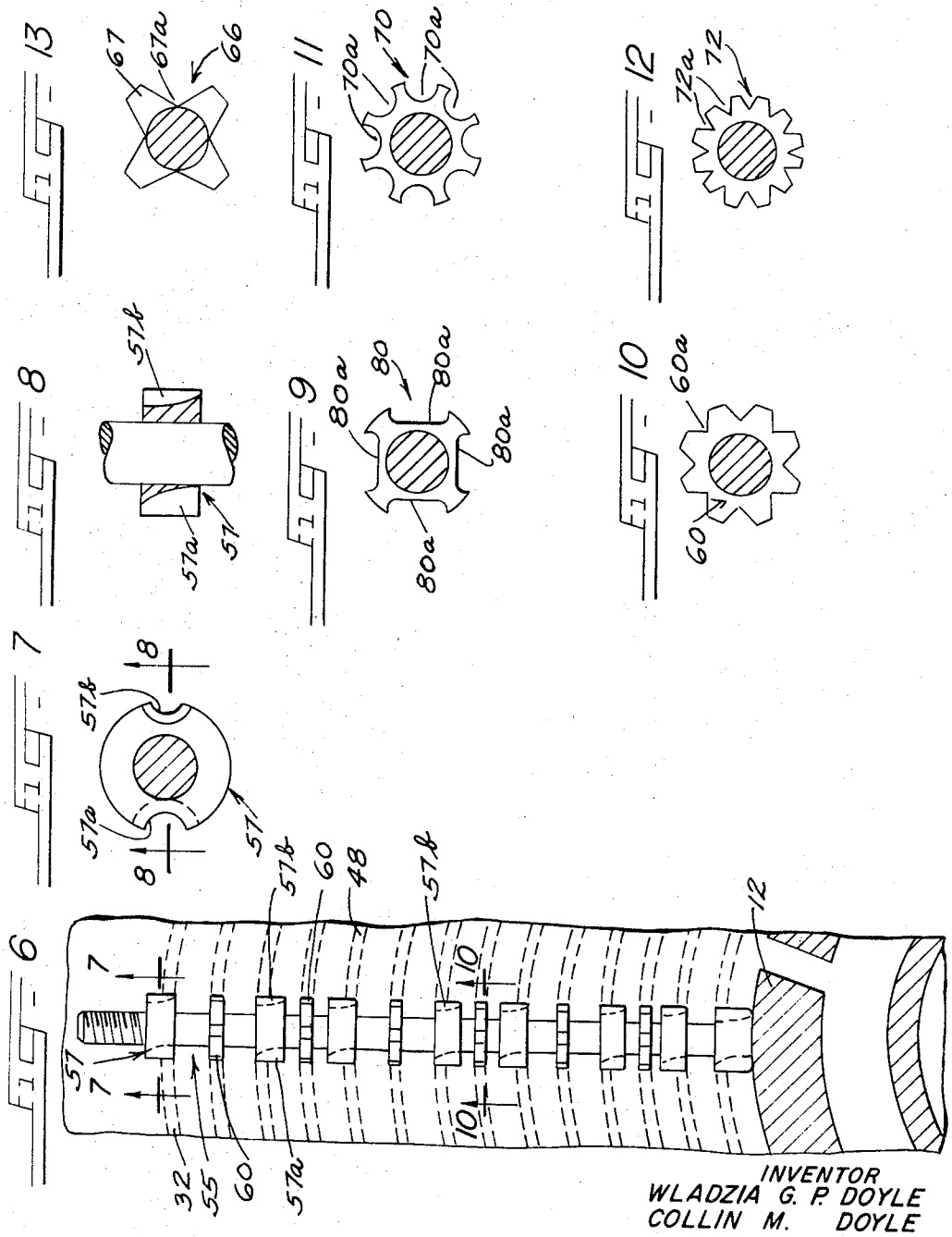


Oct. 31, 1967 W. G. P. DOYLE ET AL 3,350,000

INTEGRAL GRADIENT REMOVABLE DISC COLUMNS

Filed May 7, 1965

3 Sheets-Sheet 2



INVENTOR
WLADZIA G. P. DOYLE
COLLIN M. DOYLE

BY Mullen & Alter
ATTY

Oct. 31, 1967 W. G. P. DOYLE ET AL 3,350,000

INTEGRAL GRADIENT REMOVABLE DISC COLUMNS

Filed May 7, 1965 3 Sheets-Sheet 3

Fig. 14

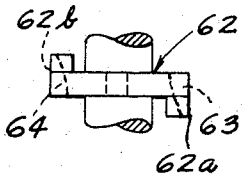


Fig. 17

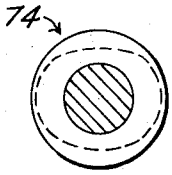


Fig. 19

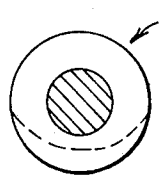


Fig. 15

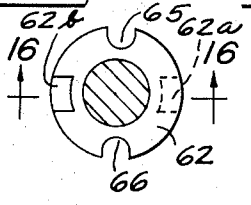


Fig. 18

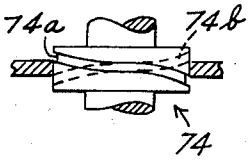


Fig. 20

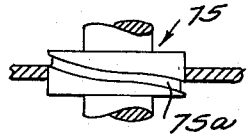
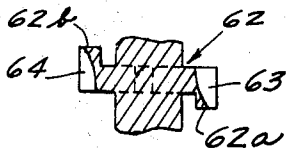


Fig. 16



INVENTOR
WLADZIA G.P. DOYLE
COLLIN M. DOYLE
BY
Mullen & Alter
Atty

United States Patent Office 3,350,000
Patented Oct. 31, 1967

3,350,000

INTEGRAL GRADIENT REMOVABLE DISC COLUMNS

Wladzia G. P. Doyle and Collin M. Doyle, both of 21 W. Elm St., Chicago, Ill. 60610

Filed May 7, 1965, Ser. No. 453,940
13 Claims. (Cl. 233—15)

ABSTRACT OF THE DISCLOSURE

A centrifugal countercurrent exchange device including a plurality of spaced bands formed with holes arranged to afford radially extending cavities. Elongated disc column members are removably positioned one in each cavity. Each disc column member comprises a rod with a plurality of integrally formed disc-like protuberances spaced apart so that each protuberance is in radial alignment with one of the bands.

This invention relates generally to centrifugal countercurrent exchange or contacting devices of the type disclosed in U.S. Patents Nos. 3,107,218, 3,114,706, and 3,132,100. More particularly, the invention relates to improvements in such devices which enable a single standardized device or machine to be readily adapted for substantially universal use under all conditions of operation. The improvements taught herein, although illustrated in connection with miniature or laboratory sized devices, are equally applicable to full scale countercurrent contacting or exchange devices.

In the aforementioned patents, the need for having a single standardized device which is readily adaptable for substantially universal use was amply demonstrated. However, to repeat briefly, efficient intimate mixing of the two fluids in the rotor makes it essential that the fluids must first be broken up or dispersed into small droplets for each mixing stage. The dispersal or "tearing up" of the fluids into small droplets for each mixing stage is the most important single requirement, since it not only enables the fluids to be more intimately mixed, but it also is directly related to the mixing energy within the rotor. Thus, where the two liquids being processed are varied and they have different characteristics such as for example different specific gravities or viscosities, the machines must be designed with different dispersal characteristics to vary the mixing energy within the rotor. We have found that one of the most effective ways of controlling the dispersal characteristics of a machine to render the same suitable for universal use, is to incorporate removable and/or adjustable disc columns therein.

In applying this principle to laboratory or miniature models of our larger contacting devices, it was found that the disc columns we previously taught in the aforementioned patents were unsuitable. Being that the machines were reduced in size, the diameters of the discs used in the disc columns were very small so that it was practically impossible to effectively perforate the discs thereof in the manner that we did in the patents aforesaid.

To obviate the difficulty of providing the disc columns which have discs perforated to effectively vary the dispersal characteristics of a miniature or laboratory type machine, we have provided disc columns with discs that have peripheral indentations formed therein. The peripheral indentations are substantially aligned with respective contacting bands and cooperate therewith to define orifices through which liquids can flow in a similar manner as they could through a perforated disc of our aforementioned patents.

It is, therefore, an important object of this invention to

to provide an improved centrifugal countercurrent contacting or exchange device having improved means for readily varying and controlling the mixing energy within said device.

It is still another object of this invention to provide a centrifugal countercurrent contacting or exchange device of the character described, having means for readily varying and controlling the dispersal characteristics as required by the characteristics of the liquids being processed.

It is still even a further important object of this invention to provide a centrifugal countercurrent contacting or exchange device of the character described, having means for readily varying and controlling the dispersal characteristics or mixing energy in a miniature or laboratory model.

It has been found that the exchange between the liquids or contacting efficiency thereof is greatly impaired by internal entrainment or reverse flow of liquids when the liquids flow through separator bands and/or discs. To obviate this problem, we have provided disc columns having discs which are formed to reduce the internal entrainment or reverse flow of the liquids. To form a disc in such fashion, the peripheral indentations of the discs are venturied or have gradually decreasing areas in a downstream direction with respect to the respective liquids flowing therethrough to cause the liquids to contact imperforate portions of the discs. The indentations thus form passages throughout the disc columns as will be more fully explained hereinafter.

It is, therefore, another important object of this invention to improve the exchange efficiency in a centrifugal countercurrent contacting or exchange device of the character described by reducing the internal entrainment or reverse flow of liquids therein.

It is still a further object of this invention to provide an improved centrifugal contacting or exchange device having disc columns with discs shaped to reduce the entrainment or reverse flow of liquids therein.

It is still further an important object of this invention to provide a universally adjustable centrifugal exchange or contacting device with improved exchange or contacting efficiency.

An advantage that we have been able to attain through our invention arises from fabricating the disc columns integrally so that the discs are an integral part of the shaft or rod. Thus, our new disc columns can be inexpensively fabricated.

It is therefore still another object of our present invention to provide a new and improved disc column that is inexpensive due to integral fabrication.

With the foregoing and other objects in view which will appear as the description proceeds, the invention consists of novel features of construction, arrangement and combination of parts hereinafter fully described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes in the form, proportion, size and minor details of the structure may be made without departing from the spirit or sacrificing any of the advantages of the invention.

For the purpose of facilitating an understanding of our invention, we have illustrated in the accompanying drawings the preferred embodiments thereof, from an inspection of which, when considered in connection with the following description, our invention, its mode of construction, assembly and operation, and many of its advantages should be readily understood and appreciated.

Referring to the drawings in which like characters of reference are employed to indicate corresponding or similar parts throughout the several figures of the drawings:

FIG. 1 is a fragmentary vertical sectional view of a

centrifugal exchange or contacting device with interchangeable disc columns embodying the principles of our invention;

FIG. 2 is an enlarged vertical sectional view of an improved disc column embodying the principles of the invention and showing its relationship to the shaft of a rotor;

FIG. 3 illustrates sectional views of the discs in FIG. 2 and it is taken on planes passing through the lines **3—3** in FIG. 2;

FIG. 4 is similar to the views taken in FIG. 3 illustrating another arrangement of the discs wherein the peripheral indentations of the discs are illustrated as linearly graduated in an inverse direction with respect to the ones shown in FIGS. 2 and 3;

FIG. 5 is a view similar to FIG. 3 illustrating discs with arcuate peripheral perforations and merely showing the outer discs;

FIG. 6 is a view similar to FIG. 2 and illustrating still another embodiment of our invention wherein some of the discs have peripheral indentations that are graduated in area, or venturied;

FIG. 7 is a sectional view taken along a plane passing through the line **7—7** in FIG. 6 and illustrating the configuration of one of said venturied discs;

FIG. 8 is a sectional view taken along the line **8—8** in FIG. 7;

FIG. 9 is a sectional view similar to FIG. 7 and illustrating a modified disc;

FIG. 10 is a cross-sectional view of FIG. 6 taken along the line **10—10** and illustrating a cross-section of an intermediate disc thereof;

FIGS. 11, 12 and 13 are views similar to FIG. 7 and illustrate alternate embodiments for intermediate discs which can be used instead of the ones illustrated in FIGS. 6 and 10;

FIG. 14 is an elevational view illustrating a portion of a disc column with a modified disc which can be substituted for the venturied discs in a disc column such as illustrated in FIG. 6;

FIG. 15 is a sectional view of FIG. 14 taken on a plane passing through the line **15—15**;

FIG. 16 is a sectional view of FIG. 15 taken on a plane passing through the line **16—16**;

FIG. 17 is a view similar to FIG. 7 which illustrates a modified disc with a pair of peripheral indentations that are spiral passageways;

FIG. 18 is a side elevational view of FIG. 17 showing the modified disc thereof with relation to a band shown in section;

FIG. 19 is a view similar to FIG. 7 which illustrates a modified disc with a diagonal peripheral indentation; and

FIG. 20 is a side elevational view of FIG. 19 showing the modified disc thereof with relation to a band shown in section.

Referring to the drawings, our invention is embodied in laboratory or miniature type centrifugal countercurrent exchange devices **10** as illustrated in FIG. 1. Since the device is generally well known and a detailed description of it appears in the aforementioned U.S. Patents Nos. 3,107,218, 3,114,706, and 3,132,100, only so much thereof as is necessary for an understanding of the subject invention will be discussed. The device thus comprises a shaft **12** suitably journalled for rotation in a conventional supporting structure not shown. A rotor **16** is rigidly connected to the shaft **12** for rotation therewith, and the entire device may be enclosed in any type of removable protective cover.

Suitable passageways such as **18** are provided in the shaft **12** for respectively supplying the heavier liquid to the central area of the rotor **16** as illustrated in FIG. 2, and removing the lighter liquid therefrom. Similarly, suitable passageways (not shown) are provided for respectively supplying the lighter liquid under pressure to the peripheral area of the rotor **16** and removing the heavier liquid therefrom. Communicating with these passageways are passageways **26**, provided between the spill-over discs **28** as indicated. The contacting or separator bands **32** may be slightly perforated or preferably completely imperforate over the entire area save for a plurality of holes arranged in aligned relationship to afford a series of disc column cavities such as **34**, **35**. Also, the contacting bands are preferably illustrated as being concentric bands with gradually increased spacing to the outside of the rotor.

Removably positioned within each of the cavities **34**, **35** is one of our novel integral gradient disc columns **42**. The disc columns **42** (see FIG. 2) comprise a central rod **41** preferably circular in cross section throughout its length. As seen in FIG. 2, the rod **41** terminates at one end with a threaded portion **41***a*, and at the other end with a protuberance or bearing disc **45** which abuts against the shaft **12** when in its operative position.

In this preferred embodiment, the disc column **42** is integrally formed by means of casting or other well known means and the rod **41** therefore has the bearing disc **45** and other disc-like protuberances **46** extending integrally therefrom as illustrated in FIGS. 1 and 2.

Each of the discs **46** are preferably formed with a plurality of peripheral indentations **46***a* and are radially spaced along the rod **41** to substantially align with the bands **32** as illustrated in FIGS. 1 and 4. The discs are sized in diameter to approximate the size of the respective disc column cavities or holes **34**, **35** in order that indentations **46***a* form orifices with the defining edges of the holes or cavities in the bands **32**. Although any size and shaped peripheral indentations can be employed in our invention, in FIGS. 2 and 3 we illustrate peripheral indentations which have planar surfaces defining the sides thereof. It will be noted that the indentations are preferably graduated linearly in cross sectional area from the outside area of the rotor **16** to the shaft as illustrated in FIG. 3. The peripheral indentations could be linearly graduated in an inverse direction with the smaller area at the axis and larger area at the outside of the rotor as illustrated in FIG. 4. Still further, it will be noted that the peripheral indentations of adjacent discs are disposed 180° from each other in order that when the liquids flow through the peripheral indentations, they contact the imperforate regions of an adjacent disc.

In FIG. 5, another embodiment of the disc column **42** is suggested wherein discs **50** with arcuate peripheral indentations **50***a* are illustrated. Only the inner and outer discs are shown to illustrate that the cross sectional areas of the peripheral indentations **50***a* can be graduated linearly if formed on a rod as illustrated in either FIG. 3 or 4.

From FIGS. 1 and 2, it can be seen that the disc columns **42** can be operationally retained in the rotor **16** by moving them through the port holes **16***a* of the rotor to a position where the bearing discs **45** thereof abut against the shaft **12**. In order to removably associate the disc columns with the rotor **16**, threaded plugs **50** are provided for association with the rotor and the threaded portions **41***a* of the rod **41**. Thus, the disc columns can be locked into position by merely rotating the plugs **50** to the position illustrated in FIG. 1.

As mentioned earlier, in order to obviate entrainment or reverse flow of liquids, we have provided a modified disc column **55** as in FIG. 6 which is of similar construction to the aforementioned disc column **42** and it has venturied discs **57** with first and second peripheral indentations **57***a*, **57***b*. Each venturied disc has a gradually decreasing area in a downstream direction with respect to the respective liquids flowing therethrough. Also provided in the disc column are intermediate discs **60** interposed between each of the venturied discs **57** as illustrated in FIG. 6. The intermediate discs **60** have peripheral indentations **60***a* and are positioned so that the liquids flow-

ing through the venturied discs contact the imperforate portions of the intermediate discs and thereafter are forced through the peripheral indentations **60***a* thereof.

From FIGS. 7 and 8, it can be seen that the peripheral indentations **57***a*, **57***b* are sized differently and they are venturied in opposite directions. The first indentations **57***a* are all in substantial radial alignment and have gradually decreasing cross sectional areas in an outward or downstream direction with respect to the heavier liquid being forced radially outward from the shaft **12** of the rotor. The second peripheral indentations **57***b* are also in radial alignment with each other and are venturied in a downstream direction with respect to the light liquid which is forced under pressure toward the axis **12** of the rotor **16**. Thus, the peripheral indentations **57***b* have their larger area facing to the outside of the rotor and each of the areas thereof gradually decrease in an axial or downstream direction. It should be noted that although the peripheral indentations illustrated in FIG. 6 are shown as being respectively equal for each disc, they could be gradiently graduated as in our disc column illustrated in FIG. 2. Also, by the venturied discs **57** having a greater thickness than the bands **32**, the peripheral indentations **57***a*, **57***b* thereof act as orifices or conduits for the liquids flowing therethrough to guide the same into contact with the imperforate regions of the intermediate discs and thereby create better dispersal of the liquids to obviate entrainment.

In FIGS. 14, 15 and 16, we have illustrated a modified venturied disc **62** which can be used in place of the disc **57** illustrated in our modified disc column **55** in FIG. 6. These discs have projections **62***a*, **62***b* extending therefrom in opposite directions and disposed on a quadrant of the discs 180° apart along the periphery thereof. The projections **62***a*, **62***b*, respectively have first and second venturied peripheral indentations **63**, **64** therein, and the indentations are formed through the discs and projecting portions so that the cross sectional areas thereof decrease in the direction of extension of the projections. Thus, as respective liquids flow through the venturied disc **62**, they are guided into contact with the intermediate discs of the disc columns **55**. As will be seen in FIGS. 14 through 16, the modified venturied discs **62** also can have arcuate peripheral indentations **65**, **66** formed 180° apart at the other quadrant thereof. These peripheral indentations are not venturied and have the same effect as the ones illustrated in FIG. 2.

As can be well imagined, discs having different types of peripheral indentations formed therein can take on several different configurations. For instance, in FIG. 13, we show another modified disc **66** having truncated projections **67** extending therefrom and defining the peripheral indentations **67***a* therebetween with the planar sides thereof. In FIG. 11, we show another modified disc **70** having arcuate peripheral indentations **70***a* formed therein around the periphery thereof. In FIG. 12, we show another modified disc **72** which has several small peripheral indentations **72***a* formed therein in a similar manner to the discs illustrated in FIGS. 6 and 10. In FIGS. 17, 18, 19 and 20, we illustrate disc structures **74** and **75** that have peripheral indentations formed thereon which extend diagonally along the periphery thereof instead of radially as in the other discs. In FIGS. 17 and 18, the discs **74** have a pair of peripheral indentations **74***a* and **74***b* which are in the form of spiral passageways extending diagonally along the periphery and communicating with both sides of the contacting bands when they are aligned therewith as illustrated in FIG. 18. In FIGS. 19 and 20, the disc **75** merely has one peripheral indentation extending diagonally therealong in the form of a spiral passageway **75***a* which communicates with both sides of a separator band as illustrated in FIG. 20.

In those situations where great liquid flow is desired through the disc column, larger peripheral indentations may be formed in the discs. Thus, in FIG. 9, we show an example of a disc **80** having substantially rectangular peripheral indentations **80***a* of long length formed therein.

From the foregoing description and drawings, it should be apparent without further explanation that we have provided a countercurrent exchange device including a novel and improved disc column which is suitable for miniature or laboratory devices and it fulfills the other stated objects of our invention in a remarkably unobvious and unexpected fashion. The discs of our new disc columns have peripheral indentations to serve as orifices with the bands and thus obviate the necessity for forming perforations therein. Also, our new disc columns prevent entrainment by causing the liquids flowing therethrough to collide with an imperforate portion of an adjacent disc. Still further, by forming the discs with venturied peripheral indentations, we have provided a means for both guiding the flowing liquids against an adjacent disc and increasing the velocity of the liquids as they flow through the venturied indentations. The venturied indentations in being graduated in size in a downstream direction with respect to the respective liquids flowing therethrough bring about such an effect.

It should be realized that although our invention is described with relation to integrally formed disc columns, the principles thereof would be equally applicable to disc columns which are not integrally formed. The concept of having peripheral indentations acting as orifices in disc columns is completely novel and should not be limited to a specific form of disc column. Also, the concept of eliminating entrainment or back flow in disc columns by use of venturied peripheral indentations and intermediate discs could be applicable to any type of disc columns whether they be integrally formed or whether they are intended for miniature or regular size contacting devices.

Still further, it is believed that our invention, its mode of construction and assembly, and many of its advantages should be readily understood from the foregoing without further description, and it should also be manifest that while a preferred embodiment of the invention has been shown and described for illustrative purposes, the structural details are nevertheless capable of wide variation within the purview of our invention as defined in the appended claims.

What we claim and desire to secure by Letters Patent of the United States is:

1. In a centrifugal countercurrent exchange device including a rotor, a plurality of spaced bands positioned in said rotor, said bands being formed with holes arranged to afford a plurality of radially extending cavities, integrally formed disc columns removably positioned in said cavities, each of said disc columns comprising a rod with a plurality of integrally formed radially spaced protuberant discs arranged so that each disc is in radial alignment with a respective band, means for removably retaining said columns in said holes, each of said discs being sized to approximate the size of a respective hole of said respective band, at least some of said discs being formed with peripheral indentations in order that the peripheries of said discs form orifices with the defining edges of the holes in said bands, said disc columns being interchangeable with other disc columns whereby different conditions of dispersion may be obtained within said rotor by interchanging said disc columns with other disc columns which have integrally formed discs with different dispersal characteristics.

2. A centrifugal countercurrent exchange device, as defined in claim **1**, wherein said indentations of each of said discs are linearly graduated in size from one end of said disc column to the other.

3. In a centrifugal countercurrent exchange device including a cylindrical rotor having an axial shaft, a plurality of radially spaced concentric contacting bands positioned in said rotor, said bands being formed with holes arranged to afford a plurality of radially extending cavities, one in alignment with the other, integrally formed

disc columns removably positioned in said cavities, each of said disc columns comprising a rod with a plurality of integrally formed radially spaced protuberant discs arranged so that each disc is in radial alignment with a respective band, a plurality of portholes formed in the outer cylindrical wall of said rotor, one in alignment with the other, a plug removably positioned in each of said portholes, said disc columns being removably associated with said plugs in order that said columns are removably retained in said holes, each of said discs being sized to approximate the size of a respective hole of said respective band and being arranged in radially spaced relationship in order that one of said discs is in alignment with each of said bands, said discs being formed with peripheral indentations and substantially accurately filling said respective holes in order that the indentations of said discs form orifices with the defining edges of the holes in said bands, said disc columns being interchangeable with other disc columns whereby any condition of dispersion may be obtained within said rotor by interchanging said disc columns with other disc columns which have integrally formed discs with different dispersal characteristics.

4. A centrifugal countercurrent exchange device, as defined in claim 3, wherein said indentations of each of said discs are linearly graduated in size from one end of said disc column to the other.

5. In a centrifugal countercurrent exchange device including a rotor, a plurality of spaced bands positioned in said rotor, said bands being formed with holes arranged to afford a plurality of radially extending cavities, disc columns removably positioned in said cavities, each of said disc columns comprising a rod with a plurality of integrally formed radially spaced protuberant discs arranged so that each disc is in radial alignment with a respective band, means for removably retaining said columns in said holes, each of said discs being sized to approximate the size of a respective hole of said respective band, at least some of said discs being formed with peripheral indentations in order that the indentations of said discs form orifices with the defining edges of the holes of said bands, each said peripheral indentation having a graduated cross section that decreases in a downstream direction with respect to the respective liquids flowing therethrough in order that said flowing liquids contact an adjacent disc for dispersal, said disc columns being interchangeable with other disc columns whereby any condition of dispersion may be obtained within said rotor by interchanging said disc columns with other disc columns which have protuberant discs with different dispersal characteristics.

6. A centrifugal exchange device, as defined in claim 5, wherein each of said peripheral indentations decrease in the same direction with the larger cross sectional area portions of said indentations being all on one side of said discs and the smaller cross sectional area portions of said indentations being all on the other side of said discs.

7. A centrifugal exchange device, as defined in claim 6, wherein said some discs have venturied arcuate surfaces defining said peripheral indentations.

8. A centrifugal exchange device, as defined in claim 5, wherein said peripheral indentations consist of at least one diagonal passageway extending along the periphery and communicating with both sides of said bands.

9. A centrifugal exchange device as defined in claim 5, wherein said peripheral indentations consist of at least one spiral passageway extending along the periphery and communicating with both sides of said bands.

10. A centrifugal exchange device, as defined in claim 5, wherein said some discs have at least a pair of indentations identified as first and second, each of said first indentations being in substantial radial alignment and having gradually decreasing cross sections in a downstream direction with respect to one of said liquids flowing therethrough, each of said second indentations being in substantial radial alignment and having gradually decreasing cross sections in an opposite direction with respect to said first indentations whereby said second indentations have gradually decreasing cross sections downstream with respect to the other liquid flowing countercurrent to said one liquid.

11. A centrifugal exchange device, as defined in claim 10, wherein each of said first peripheral indentations have the larger cross sectional area portions all on one side of said discs and the smaller cross sectional area portions of said indentations all on the other side of said discs, and said second peripheral indentations have gradually decreasing cross sectional areas with the larger cross sectional area portions all located on the opposite side of said discs with respect to said larger cross sectional areas of said first indentations.

12. In a centrifugal countercurrent exchange device for processing liquids including a rotor, a plurality of spaced bands positioned in said rotor, said bands being formed with holes arranged to afford a plurality of radially extending cavities, members for controlling the flow of liquids through said device removably positioned in said cavities, each of said members comprising a rod having reduced diameter portions spaced apart to define a plurality of disc-like protuberances, each of said protuberances positioned in radial alignment with one of said bands, whereby the droplet dispersal characteristics of the device may be controlled, and means for retaining said members in said cavities.

13. The centrifugal countercurrent exchange device of claim 12 in which said protuberances are formed with peripheral indentations, said indentations and the adjacent wall portions of the holes in said bands forming orifices through which said liquids flow, said members being interchangeable with other members having different indentations whereby the droplet dispersal characteristics of the device may be varied.

References Cited

UNITED STATES PATENTS

3,107,218	10/1963	Doyle	233—15
3,114,706	12/1963	Podbielniak	233—15
3,116,246	12/1963	Podbielniak	233—15
3,132,100	5/1964	Podbielniak	233—15

HENRY T. KLINKSIEK, *Primary Examiner.*