Jan. 25, 1966 H. D. SCHRIER 3,231,242

MIXING DEVICE

Filed April 17, 1962 3 Sheets-Sheet 1

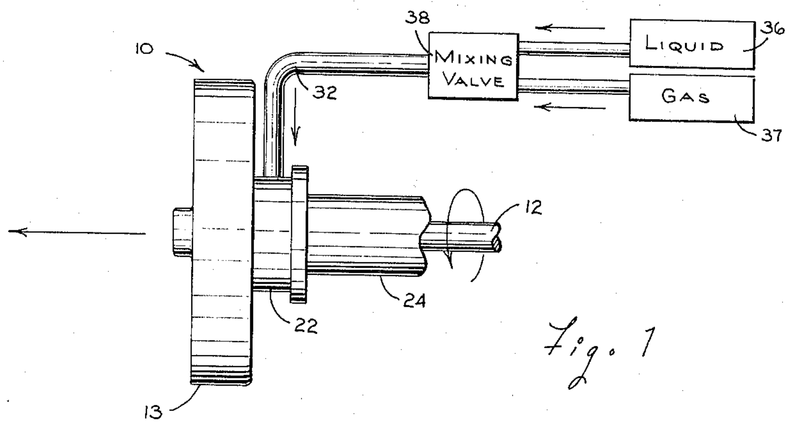

Fig. 1

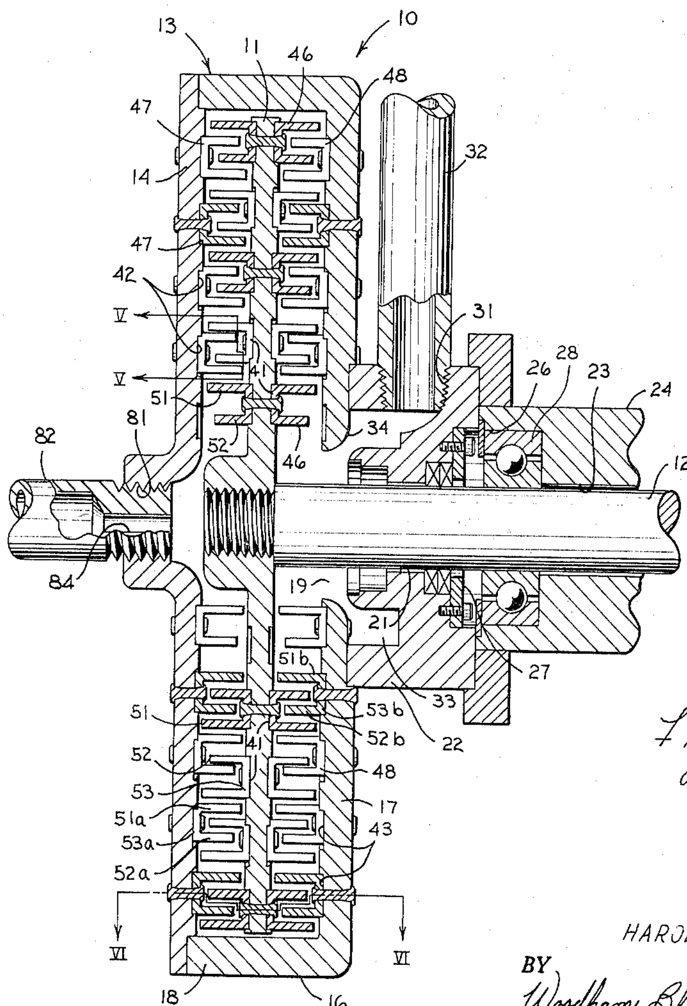

Fig. 3

INVENTOR.
HAROLD D. SCHRIER
BY Woodhams, Blanchard & Flynn
ATTORNEYS

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MIXING DEVICE

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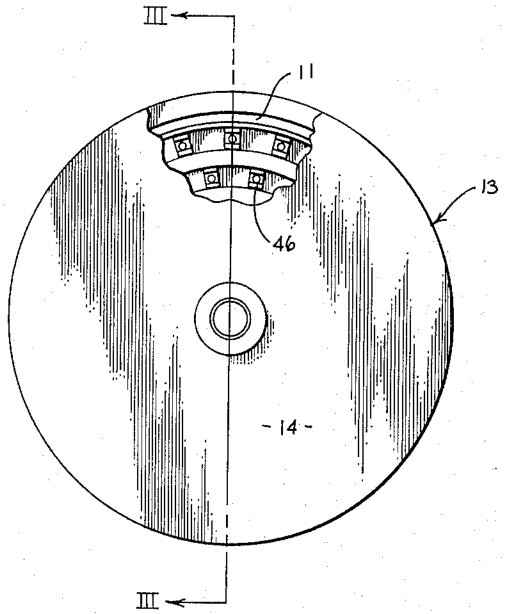

Fig. 2

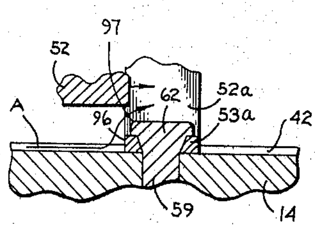

Fig. 7

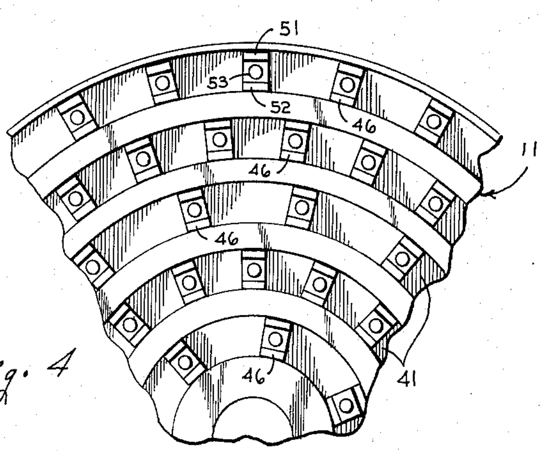

Fig. 4

INVENTOR.
HAROLD D. SCHRIER

BY
Woodhams, Blanchard & Flynn
ATTORNEYS

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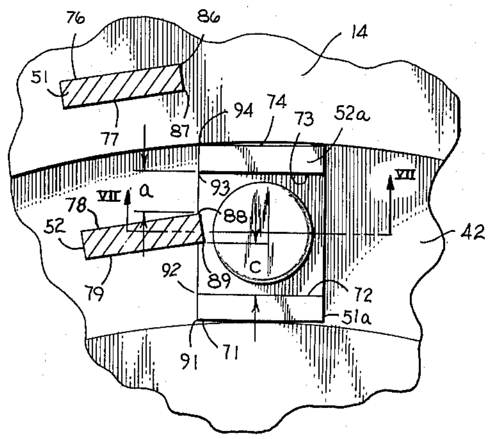

Fig. 5

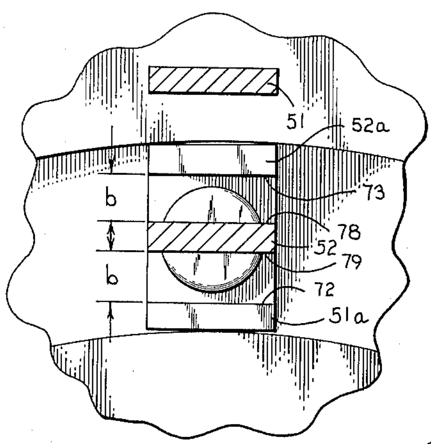

Fig. 5a

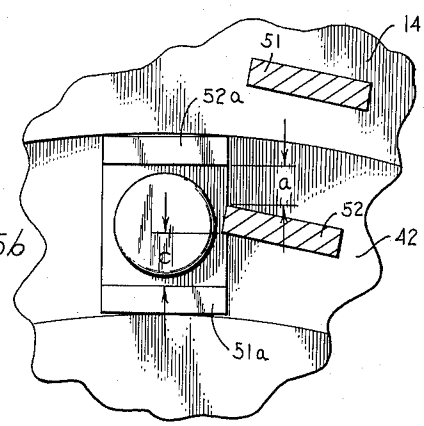

Fig. 5b

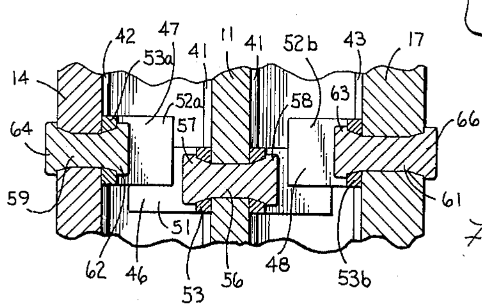

Fig. 6

INVENTOR.
HAROLD D. SCHRIER

BY

Woodhams, Blanchard and Flynn
ATTORNEYS

United States Patent Office 3,231,242
Patented Jan. 25, 1966

3,231,242
MIXING DEVICE

Harold D. Schrier, 3405 Winchell Ave., Kalamazoo, Mich.
Filed Apr. 17, 1962, Ser. No. 188,203
5 Claims. (Cl. 259—7)

This invention relates to improvements in apparatus for mixing materials and, more particularly, relates to an apparatus for mixing together a plurality of substances, such as two immiscible liquids, a gas and a liquid, or a fluid and a pulverized solid.

The treatment of a plurality of substances to effect a uniform mixing thereof is widely carried out in industry. Such treatments include the mixing of a gas and a liquid to form a cellular product, such as a foam, the mixing of two immiscible liquids to form an emulsion and the mixing of fluids with a pulverized solid to form a suspension. Other uses include the contacting of two substances, for example, to effect a chemical reaction therebetween.

The apparatus of the invention was devised particularly to improve procedures for generating a foam for use with gypsum to form a lightweight, foamed, gypsum product which can be used, for example, to make a door core, wall board or similar known products. Accordingly, the following description will refer specifically thereto. It will be understood, however, that such specific description is for illustrative purposes only and that the invention is useful for a wide variety of mixing operations.

The formation of a foam intended for use in a gypsum slurry involves the mixing of a gas, commonly air, with water containing a foaming agent, such as a foaming agent of the class described in my co-pending application Serial No. 91,587, filed February 27, 1961, now abandoned. Such a foam should be stable, fine-celled and of uniform density. In order to produce such foams with the prior art mixing apparatus and methods, it has been necessary to use a considerably greater amount of foaming agent than theoretically is required to form an acceptable foam. This has been done in order to insure that each part of the foam has at least the minimum amount of foaming agent therein necessary to provide an acceptable foam even though there may be an excess of foaming agent in other parts of the foam.

Further, it is desired to produce a foam having a small average pore size while at the same time providing a high foam production rate for a foaming unit of any given size. This involves a substantial problem because the formation of a foam involves subdividing relatively large bubbles of gas, such as air, to form smaller bubbles or pores. In order to reduce the size of the bubbles, it is necessary either to use larger machines so that a greater amount of subdivision can take place or to reduce the clearances between the mixing elements and also to reduce the quantity of the material fed through the machine. This either increases the equipment costs or decreases the foam generating capacity of the equipment. Moreover, even these procedures may not have the desired effect.

Accordingly, it is an object of this invention to provide a mixing apparatus which is capable of mixing many different types of materials in an improved manner.

Further, it is an object of this invention to provide a mixing apparatus, as aforesaid, which is capable of effecting a highly satisfactory mixing of the materials fed therethrough to thereby produce a uniform product.

It is a further object of this invention to provide an apparatus, as aforesaid, which is capable of forming a stable, fine-celled foam of uniform density, using a minimum amount of foaming agent.

Other objects and advantages of the invention will become apparent to persons acquainted with processes and apparatus of this type upon reading the following description and inspecting the accompanying drawings.

In the drawings:

FIGURE 1 is a side elevational view of the apparatus of the invention and schematically illustrates the means for supplying the material to be mixed thereto.

FIGURE 2 is a simplified, partially broken away, front elevational view of the apparatus shown in FIGURE 1.

FIGURE 3 is a sectional view taken along the line III—III of FIGURE 2.

FIGURE 4 is a plan view of a fragment of the rotor.

FIGURES 5, *5a* and *5b* are sectional views taken along the line V—V of FIGURE 3 and illustrating three different positions of one of the mixing elements on the rotor with respect to a stationary mixing element on the casing.

FIGURE 6 is a sectional view taken along the line VI—VI of FIGURE 3.

FIGURE 7 is a sectional view taken along the line VII—VII of FIGURE 5.

General description

In general, the invention provides a mixing apparatus in which a stream of the materials to be mixed is continuously fed into a casing having a rotor rotatably mounted therein. The rotor has a pair of axial end faces opposed to the interior surfaces of the end walls of the casing. Mixing elements are mounted upon both end faces of the rotor and these mixing elements interfit with corresponding mixing elements on said interior surfaces. The stream of material is fed through one of the end walls of the casing and flows radially outwardly between one axial end face of the rotor and the end wall of the casing opposed thereto. The stream then passes around the periphery of the rotor and flows radially inwardly between the other axial end face of the rotor and the end wall opposed thereto. As the rotor is rotated within the casing, the mixing elements effect a shearing and agitation of the material passing through the casing. Thus, the materials comprising the stream are effectively mixed so that the product exiting from the casing consists of a uniform mixture of the materials.

As applied specifically to generation of a foam, a gas, such as air, is injected into a stream of liquid which contains a foaming agent outside of the casing and this stream is then fed into the casing where the gas bubbles are subdivided to form a stable, fine-celled foam. Under certain circumstances, it is acceptable to feed the liquid and the gas separately into the casing but this is less satisfactory.

The mixing elements are arranged in concentric circular rows on the end faces of the rotor and on the interior surfaces of the end walls of the casing. Each mixing element is comprised of a pair of radially spaced, axially projecting legs. The mixing elements within a given row are spaced circumferentially from each other to provide gaps therebetween and the clearances between the legs of the mixing elements which are associated with each other are closely controlled so that an effective shearing and mixing action takes place.

Detailed description

Referring to the drawings, the mixing device **10** is comprised of a rotor **11** mounted on a shaft **12**, which shaft may be rotated by any suitable mechanism, such as an electric motor (not shown). The rotor **11** is rotatably supported within a casing **13**. The casing is comprised of an end plate **14** and a substantially cup-shaped member **16**, said end plate and said cup-shaped member being rigidly affixed to each other. The member **16** has an end wall **17** and has a cylindrical sidewall **18**. The end plate **14** and the end wall **17** are opposed to and are spaced from each other and the rotor **11** is disposed therebetween and is encircled by the sidewall **18**.

The shaft 12 extends through a central opening 19 in the end wall 17, thence through a central opening 21 in a fitting 22 into and through a further opening 23 in a housing 24. A recess 26 is provided for receiving a suitable mechanical seal 27 and a bearing 28. The seal prevents flow of the material being mixed along the shaft 12 in a rightward direction as appearing in FIGURE 3.

The fitting 22 has a substantially radially extending opening 31 to which a conduit 32 is connected whereby the materials to be mixed can be fed into the mixing device 10. The opening 31 comunicates with an annular manifold 33 surrounding the shaft 12. The manifold 33 communicates through an annular opening 34 with the central opening 19 in the end wall 17 and thereby with the interior of the casing 13.

The materials to be mixed, which are assumed for the purposes of the present disclosure to be a liquid containing a foaming agent, and a gas, are supplied from the sources 36 and 37, respectively. Pressure will be exerted upon both materials, such as by utilizing a pump for pumping the liquid and a compressor for pressurizing the gas, so that both materials are fed under pressure. The two materials are fed continuously into a mixing valve 38 which may be of any suitable, conventional construction. The two materials are mixed thereby in a preliminary fashion so that roughly equal amounts of the gas are contained in given amounts of the liquid. The stream exiting from the mixing valve is then fed through the conduit 32 into the interior of the casing 13 where it is mixed as is described in greater detail hereinbelow. If desired or necessary, a pump may be provided between the mixing valve 38 and the casing 13 to augment the feeding pressure on the stream of material entering the casing. In any event, sufficient pressure is exerted on the stream to move same through the casing 13.

The rotor 11 is a substantially flat disc and has a series of radially spaced, annular, concentric grooves 41 (FIGURE 4) on both axial faces thereof. The interior faces of the end plate 14 and end wall 17 have a similar series of radially spaced, annular, concentric grooves 42 and 43, respectively, therein. Each of the grooves 42 and 43 is associated with but is offset radially, here radially inwardly, from one of the grooves 41 on the rotor 11.

A plurality of U-shaped mixing elements 46 are disposed in each of the grooves 41 and similar U-shaped mixing elements 47 and 48 are disposed in each of the grooves 42 and 43, respectively. The mixing elements 46 on the rotor 11 interfit with the mixing elements 47 and 48 on the end plate 14 and end wall 17, as described in greater detail hereinbelow, to effect a thorough mixing of the fluid stream which is fed through the casing 13.

As best illustrated in FIGURE 4 wherein one axial face of the rotor 11 is shown, the number of mixing elements 46 in the grooves 41 increases toward the periphery of the rotor. Further, the arcuate distance between any two adjacent mixing elements in any given groove 41 is different from the corresponding spacing of the mixing elements in the adjacent grooves. While the number of mixing elements in any two adjacent grooves may be the same, the radially outermost grooves have a substantially greater number of mixing elements than do the radially innermost grooves. Moreover, the mixing elements 46 in any given groove 41 are offset circumferentially from the mixing elements in the grooves 41 adjacent thereto. This arrangement of the mixing elements 46 insures that no channeling or uncontrolled motion of the stream being mixed will occur and, thereby, different parts of the fluid stream will all be subjected to substantially the same type and amount of mixing action.

For convenience in manufacture, each of the mixing elements 46 on one of the axial faces of the rotor 11 is arranged in back-to-back relationship with a mixing element on the other face so that they may be secured to the rotor by a common rivet, as described hereinbelow. However, this single rivet feature is not essential for the purposes of the invention.

The mixing elements 47 and 48 on end plate 14 and end wall 17 are arranged in the grooves 42 and 43, respectively, in the same fashion as are the mixing elements 46 in the grooves 41. The number of mixing elements 47 and 48 in any of the grooves 42 and 43 may be equal to or different from the number of mixing elements 46 in the grooves 41 associated therewith. However, the number of the mixing elements in the grooves 42 and 43 also increases toward the periphery of the end plate 14 and end wall 17, respectively. Further, the mixing elements in adjacent grooves 42 or 43 are offset circumferentially from each other for the reasons previously discussed. As shown in FIGURE 3, each of the mixing elements 47 is axially aligned with a mixing element 48 but this arrangement is not essential.

The mixing elements 46 are identical. They are substantially U-shaped and each has a long leg 51, a short leg 52 and a connecting web 53. The mixing elements 47 and 48 are substantially identical to the mixing elements 46 and corresponding parts thereof are identified by the same reference numerals with a suffix "*a*" and "*b*" applied thereto, respectively. The mixing elements 46 are arranged with their webs 53 disposed in an appropriate one of the grooves 41 with the legs 51 and 52 thereof projecting axially. The short legs 52 are in this embodiment arranged on the radially inner side of the groove 41 and the long legs 51 are on the radially outer side of the groove, although this arrangement may be reversed if desired. The mixing elements 47 and 48 are similarly arranged except that the long legs 51*a* and 51*b* are on the radially inner side of the grooves 42 and 43 and the short legs 52*a* and 52*b* are on the radially outer side of said grooves. Thus, the short legs 52 of the mixing elements 46 are adapted to travel between the legs of the mixing elements 47 or 48 associated therewith. Similarly, the short legs of the mixing elements 46 and 47 are adapted to extend between the legs of the mixing elements 46 which are associated therewith. Further details of the shape and orientation of the legs will be pointed out hereinafter.

The mixing elements 46, 47 and 48 are fixedly secured to the rotor 11, end plate 14 and end wall 17, respectively, in a carefully controlled manner to insure proper spacing therebetween. As best shown in FIGURE 6, two axially aligned mixing elements 46 on opposite axial faces of the rotor 11 are secured to said rotor by a rivet 56 which passes through said rotor. The rivet 56 has a pair of enlarged heads 57 and 58 which overlie the webs 53 of the two mixing elements 46 and thereby fixedly hold said mixing elements in the grooves 41. Similarly, rivets 59 and 61 fixedly secure the mixing elements 47 and 48 in the grooves 42 and 43. The enlarged heads 62 and 63 on rivets 59 and 61 overlie the webs 53*a* and 53*b* and the enlarged heads 64 and 66 overlie the axially remote surfaces of the end plate 14 and end wall 17.

After the initial riveting operation during which at least one of the enlarged heads above referred to is formed on each rivet, the heads 57, 58, 62 and 63 are cold-formed so as to have a precise shape, particularly, a precise axial depth. Such cold forming can be carried out by a coining or similar die-shaping operation. Thus, the spacing between the free ends of the short legs 52, 52*a* and 52*b* and the opposing surface of rivet heads 57, 58, 62 and 63 is precisely controlled. Where a fine-celled foam is to be generated, the spacing between the ends of the short legs and the rivet heads is made as small as possible consistent with providing a running clearance therebetween. If a coarser-celled foam is to be generated, this spacing could be larger.

As shown in FIGURES 5, 5*a* and 5*b*, the surfaces 71, 72, 73 and 74 with the legs 51*a* and 52*a* of mixing element 47 are planar and parallel with each other. Similarly, the surfaces 76, 77, 78 and 79 of the legs 51 and 52 of mixing element 46 are planar and parallel with each other. The radially innermost legs 52 and 51*a* are tangent to the circular inner edge of the grooves 41 and 42 in which they are mounted while the radially outermost legs 51 and 52*a* extend chordally with respect to the circular outer edge of the groove within which they are mounted. Since the grooves are concentric, the legs 51, 52, 51*a* and 52*a* will be parallel when they are radially aligned with each other. The legs 51*b* and 52*b* of mixing elements 48 are arranged in the same fashion as legs 51*a* and 52*a*.

Still referring to FIGURE 5, 5*a* and 5*b*, during rotation of the rotor 11, the short leg 52 of the mixing element 46 will pass between the legs 51*a* and 52*a* of the stationary mixing element 47. Because of the planar configuration of the legs, and the positioning thereof as described above, when the leg 52 is about to enter between the legs 51*a* and 52*a*, or is leaving same, the surface 78 thereof is spaced from the opposing surface 73 of leg 52*a* a distance "a" (FIGURES 5 and 5*b*) and the surface 79 is spaced from the opposing surface 72 of the leg 51*a* a distance "c." When the leg 52 is fully received between the legs 51*a* and 52*a* and is parallel therewith, as shown in FIGURE 5*a*, it is spaced from both such legs a distance "b." Distance "a" is less than distance "b" and distance "b" in turn is less than distance "c." Accordingly, as the short leg 52 passes between the legs 51*a* and 52*a*, different clearances will exist between such legs at various times and, thus, the shearing effect caused by movement of said leg 52 will vary in intensity. This has been found to improve the mixing operation and also provides a smaller and more uniform size when a foam is being generated.

The end plate 14 has a central outlet opening 81 to which is connected a discharge conduit 82. The discharge conduit 82 has a constriction of substantially uniform cross-sectional area therein for the purpose of retarding flow of material from the casing 13. This insures that the feeding pressure will remain effective on the materials within the casing so that the mixing of said materials will be performed under pressure. Here, the constriction is provided by a portion 84 of reduced internal diameter in the discharge conduit 82. While the particular manner of providing the constriction may be varied, it has been found that the constriction should be of substantially uniform cross-sectional area, particularly where a foam is being generated, in order not to detrimentally effect the uniformity of the stream of material exiting from the casing.

Operation

While the operation of the machine has been indicated before, the same will now be summarized to insure a complete understanding of the invention.

The stream of materials to be mixed is continuously fed under pressure and passes through the conduit 32 into the manifold 33, thence into the casing 13 in the form of an annular stream. The stream flows radially outwardly between the rotor 11 and the end wall 17, thence around the periphery of the rotor 11 and then radially inwardly between the rotor and the end wall 14 from whence it passes outwardly through the conduit 82. In moving through the casing 13 as above described, the entire stream does not necessarily move only radially through a completely tortuous path around the free ends of the legs of all of the mixing elements 46, 47 and 48 because of the gaps between the mixing elements. However, a substantial and controlling amount of movement of the stream does involve such a tortuous movement. During such tortuous movement, the stream in passing between the adjacent legs of two mixing elements and then around the free ends of the legs is subjected to an intense shearing action. This shearing action is particularly intense where the stream passes between the free end of the short legs 52, 52*a* and 52*b* and the rivet heads opposed thereto. The clearance between the short legs and the rivet heads is carefully determined in order to provide the desired shearing action.

While the basic movement of the material is in a radial direction with respect to the rotor 11, the material also will be moved circumferentially to some extent by the mixing elements as the rotor 11 rotates within the casing and this further increases the effectiveness of the mixing operation. The extent to which various portions of the stream are mixed with each other also is enhanced by the gaps between the mixing elements which permit a limited amount of free circumferential and radial movement of portions of the stream. However, since these gaps are small and are staggered, only a small amount of the material can move therethrough and any material which does move through a gap will be picked up and acted on by the adjacent radially outer teeth. Hence all portions of the stream will be mixed to a substantially uniform extent.

When the stream of materials is moved circumferentially within the casing, it is driven against the end surfaces of the mixing elements and passes around the sharp corners thereof. This improves the subdivision of the stream. For example, referring to FIGURE 5, the stream of materials contacts and is broken up as it passes around the sharp corners 86, 87, 88 and 89 of the legs 51 and 52 and the sharp corners 91, 92, 93 and 94 of the legs 51*a* and 52*a*. Further, referring to FIGURE 7, some of the material travels circumferentially within the groove 42 and this is driven against the end surface of the web 53*a* and then passes around the sharp corner 96 thence around the corner 97 of the rivet as indicated by the arrow A. Thus, a portion of the stream passing between the legs of any mixing element is contacted by six sharp edges, for example, the edges 92, 93, 88, 89, 96 and 97.

It is to be noted that the pressure on any given portion of the material varies somewhat from time to time because of the gaps between the mixing elements and because of the way the legs of the mixing elements are shaped and disposed. Thus, as shown in FIGURES 5, 5*a* and 5*b*, because of the different clearances which exist at different times between the legs of a given pair of mixing elements as they move relatively to each other, different pressures will be exerted on the material therebetween and the intensity of the shearing effect also will vary.

Thus, as the stream flows radially with respect to the rotor 11 it is subjected to an intense shearing by the relative movement between the mixing elements. At the same time, because of the gaps between the legs, there is some freedom of movement so that different parts of the material can be mixed effectively with each other. Further, variable shearing forces and pressures are exerted upon the material as it flows therethrough.

Considering an operation in which a foam is generated, the liquid containing the foaming agent and the gas, which have been previously mixed together at least in a rough fashion, are continuously fed as a stream through the casing 13. As this stream passes through the casing, the gas bubbles are continuously subdivided by the shearing action above described and the materials are mixed in an effective manner whereby the foam product has small gas bubbles uniformly distributed therethrough. It has been found that by the use of the present invention, the amount of foaming agent which is required to produce a stable, uniform foam is substantially less than where other types of foam generating apparatus are used, other conditions remaining the same.

While a particular preferred embodiment of the invention has been described, the invention contemplates such changes or modifications therein as lie within the scope of the appended claims.

What is claimed is:

1. A mixing apparatus comprising:

a hollow casing having a pair of axially spaced end walls and a peripheral wall extending therebetween;

a rotor rotatably mounted within said casing, said rotor having a pair of axial end faces disposed in face-to-face, spaced-apart relation with respect to the interior surfaces of said end walls;

means for admitting a stream of material to be mixed through one of said end walls into the interior of said casing;

means permittng removal of the stream of material through the other end wall of said casing;

substantially U-shaped mixing elements mounted on the end faces of said rotor and on the interior surfaces of said end walls, said mixing elements being arranged in concentric rows with the mixing elements in any given row being circumferentially spaced from each other, each of said mixing elements comprising a pair of radially aligned and radially spaced legs connected by a web, the webs of said mixing elements being mounted on said end faces and said interior surfaces, respectively, and projecting thereabove, the radial spacing between the legs of each mixing element being substantially greater than the radial thickness of the legs whereby when the legs of any one mixing element are interfitted with the legs of another mixing element spaces of substantial width are formed between adjacent legs;

fastening means securing the web of each of said mixing elements to its associated end face or interior surface, said fastening means having an enlarged head overlying and projecting away from the web of its associated mixing element, said head having a diameter substantially larger than the radial width of the legs, said head being spaced a predetermined axial distance from the free ends of the legs of the mixing elements opposed thereto;

the rows of mixing elements on said rotor being offset radially from the rows of mixing elements on said internal surfaces so that the legs of the mixing elements in any given row are interfitted with and overlap the legs on the mixing elements opposed thereto, whereby, when said rotor is rotated, each time a leg of one mixing element moves between the legs of the mixing element opposed thereto the material being forwarded through the casing will be moved into the spaces between the legs and against an edge of the web and thence between the head and the free end of the mixing element leg so that the material will be subjected to an intensive shearing and a variable compression in order to effect a uniform mixing thereof.

2. A mixing apparatus according to claim 1, in which the fastening means is a rivet and the mixing elements each have a long leg and a short leg, the short leg of any given mixing element being receivable between the legs of the mixing element opposed thereto and extending close to the rivet head thereon.

3. A mixing apparatus, comprising:

a hollow casing having a pair of axially spaced end walls and a peripheral wall extending therebetween;

a rotor rotatably mounted within said casing, said rotor having a pair of axial end faces disposed in face-to-face, spaced-apart relation with respect to the interior surfaces of said end walls;

means for admitting a stream of material to be mixed through one of said end walls into the interior of said casing;

means permitting removal of the stream of material through the other end wall of said casing;

mixing elements mounted on the end faces of said rotor and on the interior surfaces of said end walls, said mixing elements being arranged in concentric rows with the mixing elements in any given row being circumferentially spaced from each other, each of said mixing elements comprising a pair of radially aligned and radially spaced legs, the rows of mixing elements on said rotor being offset radially from the rows of mixing elements on said internal surfaces so that the legs on the mixing elements in any given row are interfitted with and overlap the legs on the mixing elements opposed thereto;

the legs of said mixing elements having planar, parallel, radially inner and outer surfaces which extend in a chordal direction with respect to the rotor;

whereby, when the rotor is rotated, each time one leg of one mixing element moves between the legs of a mixing element opposed thereto there will be a changing clearance between the legs so that the material will be subjected to a variable compression.

4. A mixing apparatus according to claim 3, in which the mixing elements are substantially U-shaped and have webs mounted on said end faces and said interior surfaces, respectively, and projecting therebeyond;

a rivet securing the web of each of said mixing elements to its associated end face or interior surface, said rivet having an enlarged, cold-formed head overlying and projecting away from the web of its associated mixing element, the rivet heads being spaced a predetermined axial distance from the free ends of the legs opposed thereto, the webs being spaced a greater distance than said heads from said free ends and the rotor face and said interior surfaces are spaced an even greater distance from said free ends;

whereby, when the rotor is rotated, each time one leg of one mixing element moves between the legs of a mixing element opposed thereto the material will be moved against an edge of the web of said latter mixing element and thence between the rivet head and the free end of said one leg so that the material will be subjected to an intensive shearing and variable compression in order to effect a uniform mixing thereof.

5. A mixing apparatus according to claim 3, in which said end faces and said interior surfaces each having a plurality of radially spaced, concentric, annular grooves therein and said mixing elements are mounted at circumferentially spaced points in said grooves, said surfaces of said legs extending in a chordal direction in said grooves.

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WALTER A. SCHEEL, *Primary Examiner.*

IRVING BUNEVICH, CHARLES A. WILLMUTH, *Examiners.*