

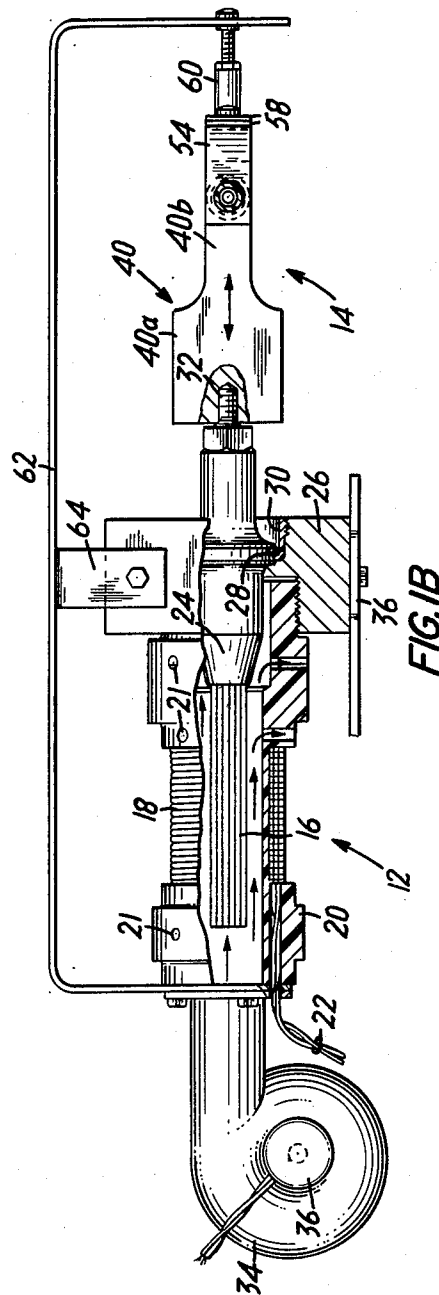
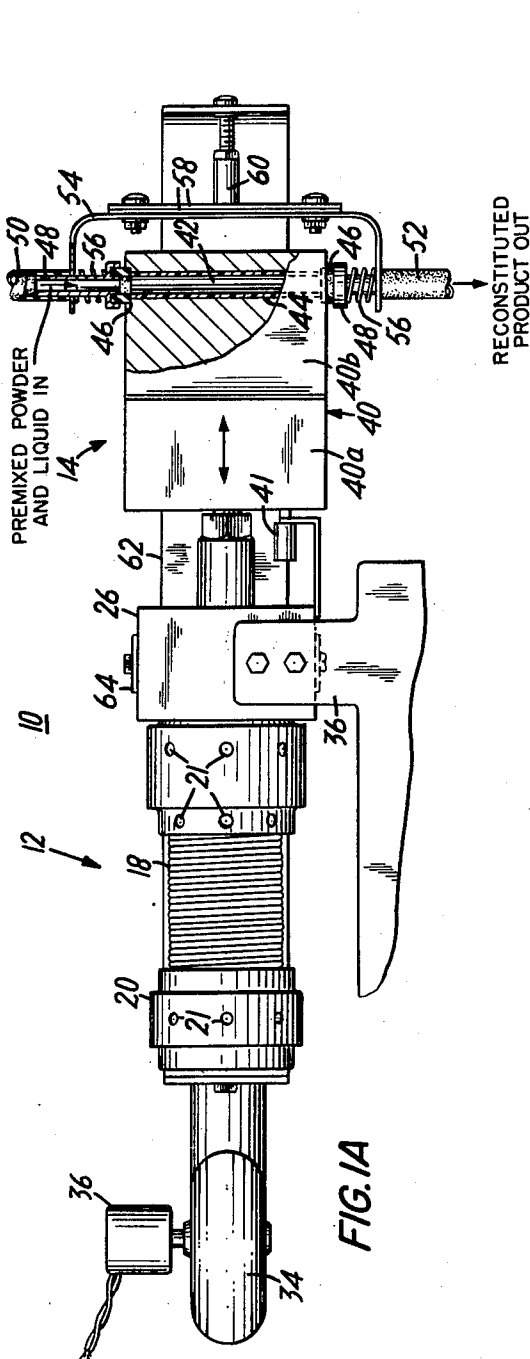
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L. BALAMUTH ET AL
ULTRASONIC MIXING APPARATUS

3,165,299

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3 Sheets-Sheet 1



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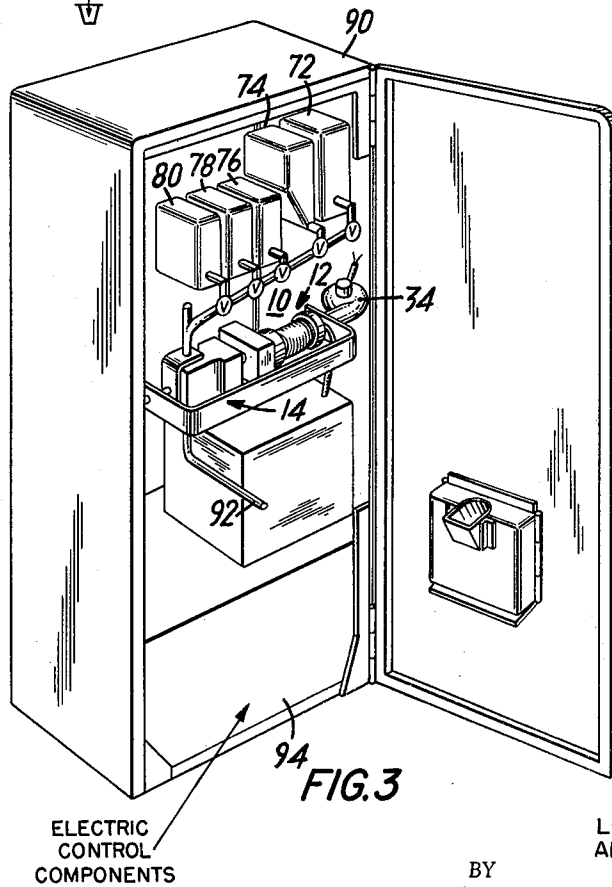
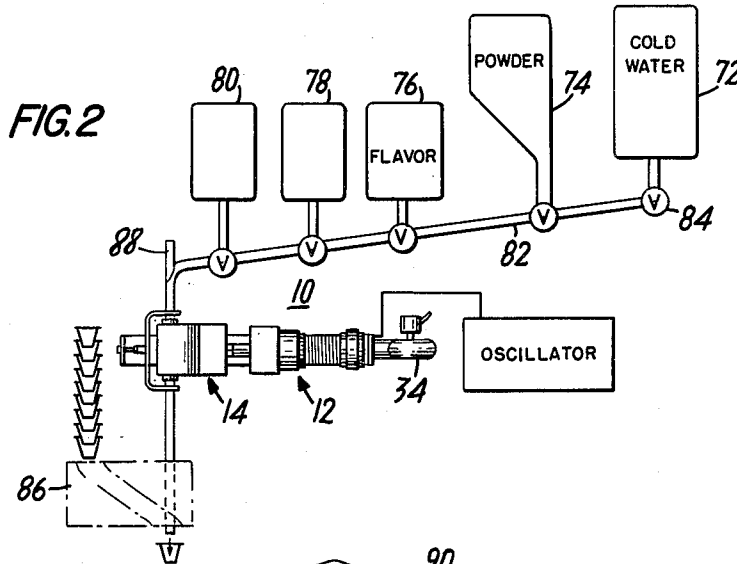
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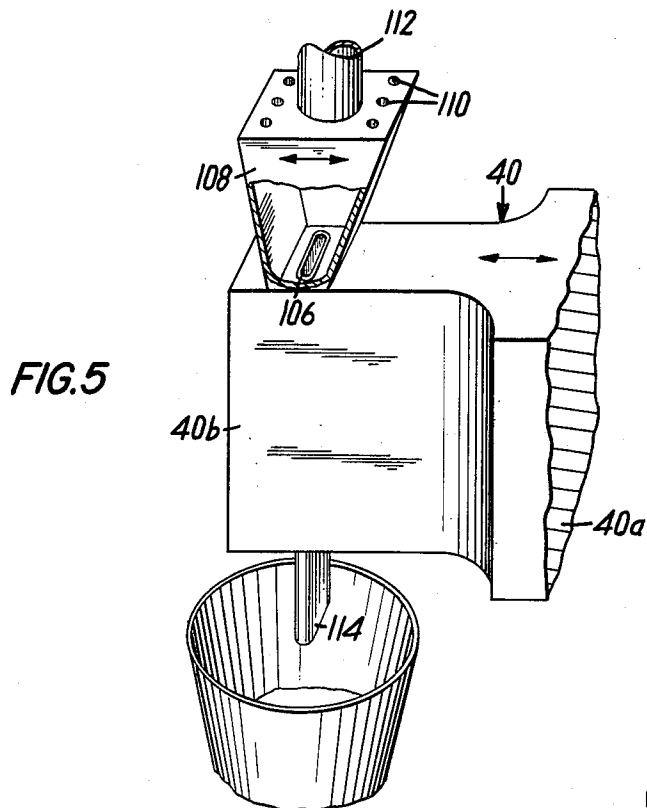
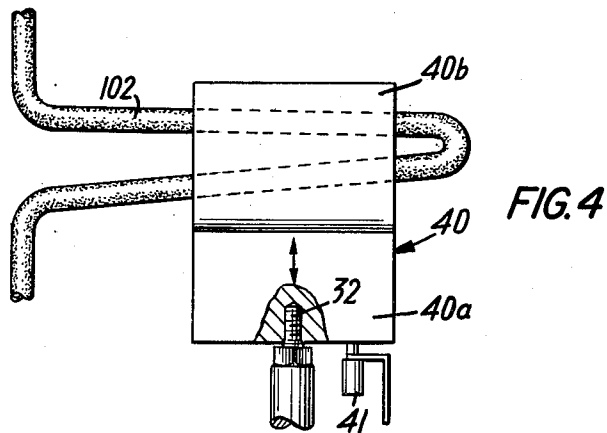
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3 Sheets-Sheet 3



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3,165,299

ULTRASONIC MIXING APPARATUS

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7 Claims. (Cl. 259—1)

This invention relates to mixing of materials by means of ultrasonic energy, and more particularly, to apparatus employing ultrasonic energy to provide dispersions of solids in liquids, especially applicable to the reconstitution or rehydration of powdered foodstuffs.

Dehydration of materials has become a widely used expedient in many fields for rendering bulk materials easier to store, handle and dispense. The food industry has been a prime user of dehydration techniques and a wide variety of food products are now available to the consumer in powdered form. In many instances, the dehydration of an otherwise perishable product enables it to be kept for extended periods of time without refrigeration or special handling. For example, milk, which normally requires constant refrigeration to prevent souring, may be reduced to a powdered state in which it can be kept without refrigeration almost indefinitely. Other products, such as soups, also enjoy the same advantages when reduced to a powdered state.

In addition to being of great convenience in restaurants, the home kitchen, etc., powdered food substances have been recognized as being potentially well suited for use in automatic vending and dispensing machines. Since they may be stored with a minimum of temperature control, and require only water for reconstitution, the construction of the dispensing machinery would be considerably simplified. Furthermore, since the powder is in greatly concentrated form, a relatively large amount of finished product could be dispensed before refilling and servicing of the machine is necessary.

However, in spite of the apparent advantages of powder food substances for vending machine application, several drawbacks are present which until now have extremely limited their use. The principal objection has been the inability to properly mix the powdered substance with the water in the relatively short time allotted to provide the customer with the finished product after he has inserted his coin. Ideally, the product should be reconstituted in its finished form as a complete dispersion of the powder in the liquid. In the home, or restaurant, considerable time may be expended for the mixing process to produce a smooth, palatable mixture, but when vending machines are used, speed of service is of prime importance. Moreover, ordinary manual or mechanical mixing methods now available are inherently unable to produce the total dispersion necessary to provide a product approaching the original in consistency and taste and, in addition, tend to produce a froth or foam which lessens the eye appeal of the reconstituted liquid.

The second obstacle presented in the use of automatic dispensing apparatus involves sanitation. Obviously, the apparatus for dispensing the foodstuffs must be maintained clean, but even when the greatest care is taken, small quantities of the reconstituted liquid will remain on portions of the mixing or dispensing mechanism and will be subject to the effects of harmful bacteria. At the present time, it is necessary to have the machines manually cleaned at relatively frequent intervals by servicemen to maintain them in sanitary condition and comply with local health requirements. The frequent attention required would seriously detract from the advantages that would be gained from the use of powdered materials.

The foregoing factors are of particular concern in the dispensing of milk or cream. Heretofore, automatic

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dispensing of milk in bulk form has not been practicable because of the storage and sanitation problems presented, and milk vending machines now provide only cartons or bottles which must be kept continuously refrigerated. Attempts to use powdered milk have been discarded because of the inability to produce a mixture of the milk powder and water which approaches the flavor and consistency of the original fluid milk. Even in connection with coffee dispensing machines, the use of powdered cream has been limited because of the failure to provide suitable mixing techniques. In the case of the latter, whole cream is generally used, requiring frequent replacement to avoid spoilage.

It has been known for some time that the application of ultrasonic energy to a mixture of liquid and powder will produce a uniform dispersion. This principle has been applied to many bulk mixing problems and some success has been achieved. It is the primary object of the present invention to provide novel ultrasonic apparatus for producing complete dispersions of powders in liquids, particularly suitable for use in vending machine applications.

A further object of this invention is to provide a novel ultrasonically actuated vibrating device for rapidly producing an intimate mixture of a plurality of materials.

Still another object of the present invention is to provide novel ultrasonically vibrating apparatus for producing dispersions wherein adherence of the mixed materials to the apparatus is reduced to a negligible minimum.

Yet another object of the invention is to provide ultrasonic mixing apparatus for liquids and solids wherein the resultant dispersion is rendered free of entrapped gases.

A still further object of the invention is to provide ultrasonically actuated mixing apparatus particularly adapted to reconstitute dehydrated foodstuffs and operating at speeds suitable for use with automatic vending machines.

In accordance with the present invention, materials to be combined, which may be a powdered food product and water, are loosely mixed in a receiving means and then conducted through a relatively narrow opening provided in an ultrasonically vibrating element, driven by suitable transducer means. The vibratory element preferably is in the form of an elongated member, longitudinally vibrated, having one or more narrow passages therethrough adjacent an area of maximum vibration and disposed transversely to the direction of vibration. As the powder and water mixture passes through the passage in the vibrating member, the dispersion is formed and, at the discharge end, the reconstituted product is available for supplying to a suitable receptacle.

The vibrating member is actuated at a frequency on the order of 20,000 cycles per second and with an amplitude which may be approximately one to two thousandths of an inch. The opening or passage in the member through which the mixture flows is made relatively small with respect to the size of the member, enabling the vibratory energy applied to it during its passage through the member to induce cavitation action therein. The violent stresses set up in the mixture during cavitation produces a rapid and complete dispersion of the powder in the liquid. The energy supplied to the materials by the vibratory action eliminates the requirement for heating the liquid which heretofore has been considered necessary to properly dissolve the powder. Thus, a mixture may be produced with the liquid at a temperature just slightly above the freezing point, enabling, for example, reconstituted cold milk to be produced directly from milk powder and ice water.

A further beneficial effect provided by the present invention is degassing of the reconstituted liquid. In any

mechanical mixing method, the agitation tends to entrap air in the liquid, rendering the product frothy or foamy. The ultrasonic mixing provided by the apparatus described herein not only avoids entrapment of air, but drives off gases inherently present in the materials to be mixed or otherwise introduced therein prior to the mixing. The result is a smooth mixture, free of bubbles or foam. The consumer is thus given his full measure of the product.

Sanitation problems in the mixing apparatus of the present invention are maintained at a minimum by providing a smooth, nonporous plastic liner for the passage through the vibrating element. The cavitation action ensuing during the mixing process, in combination with the smooth inner surface thereof, virtually eliminates any tendency of the reconstituted product to adhere to the interior walls of the passage. As a result, the mixing device may be kept clean by a simple water flushing of the mixing and discharge paths.

The transducer of the mixing apparatus may be of the magnetostrictive type, driven by a relatively low power electrical oscillator, and is readily adapted to be incorporated into vending machines similar in size to those presently used. Relatively simple electrical controls are necessary to operate the mixing apparatus and presently known coin handling and switch gear may be readily adapted to actuate the apparatus.

The foregoing and other objects, features and advantages of the present invention will become more apparent from the following detailed description of a preferred embodiment thereof, when taken in conjunction with the accompanying drawings, in which:

FIGURE 1A is a side view of the vibratory mixing apparatus in accordance with the present invention;

FIGURE 1B is a top view of the apparatus of FIGURE 1A, showing details of the mounting assembly for the input and output conduits;

FIGURE 2 is a schematic diagram illustrating the application of the mixing apparatus of FIGURES 1A and 1B to an automatic dispensing arrangement;

FIGURE 3 illustrates how the apparatus of FIGURE 2 may be incorporated in a vending machine;

FIGURE 4 illustrates an alternate embodiment of the mixing apparatus of FIGURES 1A and 1B; and

FIGURE 5 illustrates a further embodiment of the apparatus wherein improved degassing of the mixture is obtained.

The details of the mixing apparatus according to the present invention are illustrated in FIGURES 1A and 1B. As shown, the apparatus 10 comprises a transducer portion, indicated generally at 12, which drives the mixing member 14 at an ultrasonic frequency. The transducer 12 may be of any well known type capable of inducing a vibratory mechanical movement in response to the application thereto of an alternating electrical current. Preferably, this apparatus includes a stack of plates 16 of magnetostrictive material, around which is wound a magnetic coil 18, in well known fashion. The coil 18 is supported on a nonmagnetic sleeve 20 and connected via leads 22 to a source of alternating electrical energy of suitable frequency.

One end of the magnetostrictive stack 16 is rigidly fastened to an elongated connecting member 24, which is rigidly mounted in a support block 26. The connecting member 24 is provided with a peripheral depression at its midpoint which retains a rubber O-ring 28 fitting into a corresponding depression in the support block 26. A retaining ring 30 threadedly engages the block 26 to prevent movement of the O-ring and yet permit disassembly of the structure when desired. The nonconductive sleeve 20 is threadedly received in the support block 26.

Upon application of alternating current to the coil 18, the magnetostrictive stack 16 expands and contracts in length at a rate equal to the frequency of the alternating current. The resultant mechanical motion is coupled

to the connecting member 24 which is provided at its other end with a threaded portion 32 for engaging the vibratory member to be described hereinafter. The connecting member 24 is made equal in length to a half wave length at the frequency of vibration in the material of which it is formed. Consequently, its midpoint, and thus the mounting ring, is at a node of motion and may be rigidly fixed in the support block 26 without affecting its amplitude of vibration.

A blower 34, operated by a suitable motor 36, is fastened at one end of the sleeve 20, providing a stream of air over the stack 16 to dissipate the heat generated thereby during its operation. Suitable ports 21 are provided in the sleeve 20 to permit circulation of the air for adequate cooling effect.

As seen in FIGURE 1A, the entire structure including the transducer and mixing member can be supported by means such as lugs 35 bolted or otherwise secured to the support block 26. Since substantially no vibratory energy is imparted to the support block 26, by virtue of its coupling to the connecting member 24 at its nodal point, this mounting arrangement imparts no vibrational energy to the remainder of the equipment with which it is used.

The mixing member 14 comprises principally a vibrating element 40, in the form of an acoustic impedance transformer. The element 40, which may be a solid block of metal such as aluminum alloy or Monel, is made a half wave length (or an integral number thereof) long at the frequency of vibration. The portion 40a thereof coupled to the connecting member 24, is of relatively greater mass than the other or free end, 40b. The transition region between the two sections of differing mass is located at approximately the nodal or quarter wave point along its length. The difference in mass between the two halves of the element 40 effect an acoustic impedance transformation which increases the amplitude of vibration at the free end relative to the driven end in inverse ratio to their masses. A more complete discussion of the acoustic impedance transformer may be found in patent No. Re. 25,033, of the present inventors, granted August 29, 1961. For the purposes of the present invention, it is sufficient to note that the application of a relatively small longitudinal vibration to the end 40a of the element 40 will produce an amplified longitudinal vibration at its outer or free end, in the direction indicated by the arrows. Thus, the vibration induced in the magnetostrictive stack 16 is coupled through connecting member 24 and amplified in the vibrating element 40.

Adjacent the free end of the element 40, there is provided an opening or passage 42 traversing the entire width of the tool transversely to its direction of vibration. This passage is located near the free end of the element so as to be subjected to considerable amplitude of vibration. The passage 42 may be thinly lined with a smooth, nonporous plastic 44 such as nylon, over its entire length through the element 40.

For monitoring purposes, a vibration responsive device 41 may be provided on the element 40, of any suitable type capable of generating an electrical signal proportional to its amplitude of vibration. A meter may be connected thereto to enable adjustment of the transducer to produce the desired amplitude of vibration.

To couple the conduits carrying the materials to be mixed into the passage 42, special coupling means are provided to isolate the vibration of the member 40 from the supply means. Both the upper and lower ends of the element 40 are counter-bored concentrically with the passage 42 to provide seats for pads 46. The latter are made of a resilient but non-absorbent material such as closed cell silicone rubber sponge. A bushing 48, of stainless steel or other noncorrosive material includes a flange portion provided with an annular recess therein for snugly engaging the exposed end of the associated pad 46 in liquid-tight relation. The input and output

conduits 50 and 52 respectively, are tightly fitted over the outer ends of the respective bushing 48, and are preferably made of a noncorrosive plastic material such as nylon.

The bushings 48 are supported in their vertical positions by means of a U-shaped bracket 54, provided with holes in each of its arms to accommodate the corresponding bushing. Compression springs 56, one for each coupling means, are provided around the respective bushings 48 between the depending portions thereof and the arms of the bracket 54.

The center portion of the bracket 54 is bolted to a pair of stiffening member 58, to the outer of which is fastened a support post 60. As seen best in FIGURE 1B, a strap member 62 straddles the entire mixing device, having one end thereof fastened to the end of the transducer sleeve 20, and the other end bolted to the post 60. Additional supports 64 are provided for the strap 62 and are fastened to the support block 26.

During the mixing operation, the powder and liquid, which are either premixed in a receptacle provided therefor, or merely jointly introduced into a common channel, are supplied to the upper end of the input conduit 50. The mixture then flows downwardly through the bushing 48 and into the plastic lined passage 42 in the vibrating element 40. As the powder and liquid flow through the passage 42, the vibratory energy imparted thereto by the vibration of the element 40, engenders cavitation in the liquid and consequent violent agitation thereof. In addition to the mixing effect, any gases entrapped in the materials are liberated and removed from the mixture. The reconstituted and degassed mixture then exits through the lower bushing 48 and the output conduit 52 to a suitable receptacle. The entire process is continuous and the materials need not be halted while subjected to the ultrasonic vibrations.

The intense, concentrated energy imparted to the fluid during its passage through the opening 42, permits the length of the passage to be kept relatively short, while providing a suitably reconstituted product. The time for reconstitution is correspondingly brief, and enables the device to be readily adapted to automatic vending machine utilization. Furthermore, the plastic lining 44 on the passage 42, in conjunction with the cavitation action induced in the fluid, prevents adherence of any significant amount of the product to the interior of the vibratory member, thereby reducing the sanitation problem.

The coupling arrangement for joining the input and output conduits to the passage 42 in the element 40 insures that little of the vibrational energy of the element 40 is lost or coupled into the remainder of the apparatus. The cushioning effect of the silicone rubber pads 46 and the resiliency of the members 54 and 62 isolate the vibratory element 40 from the remainder of the apparatus. The springs 56 absorb any lateral motion between the vibratory element and the remainder of the structure.

A typical dispensing arrangement utilizing the mixing device of FIGURES 1A and 1B is illustrated in FIGURE 2. The apparatus may incorporate a source of cold water 72 at the desired temperature (e.g. 40°-50° F.), and a supply of milk in powdered form 74. The latter may be nonfat dry milk or whole milk, or in fact may be any powdered milk product which it is desired to reconstitute. If desired, a source of various flavors 76 and vitamins or other additives 78, 80 may also be provided to further enhance the flavor and quality of the resultant product. Each of the constituents of the final product is coupled to a common conduit 82 via suitable metering valves 84, actuated in response to operation of a suitable selection mechanism, various types of which are well known in the automatic vending art. Thus, for example, upon insertion of a coin into the receiving slot in the machine and pressing of the various selecting buttons, measured amounts of each of the constituents

are delivered to and roughly premixed in the common channel 82. Insertion of the coin will also be effective to actuate the mixing apparatus 10.

The premixed constituents then flow through the ultrasonically vibrating mixing device 10 where the mixing and degassing occur in accordance with the principles discussed hereinabove. The reconstituted product is then delivered to a cup placed in receiving position by a cup dispensing mechanism 86 of any known type. The vent stack 88 allows air removed from the liquid during the degassing operation to escape from the otherwise closed system.

FIGURE 3 illustrates the mounting of the apparatus of FIGURE 2 in a cabinet corresponding to those commonly used for automatic vending machines. The water, powdered milk and other constituents are located in suitable containers as shown and a simple water cooling apparatus provided to maintain the water temperature at the desired level. Refrigeration of the entire cabinet is not necessary. The mixing device 10 is mounted as shown in the cabinet 90 and the output conduit 92 arranged to communicate with the cup holder through which the consumer may remove the filled cup. The control circuitry for the various conventional vending machine operations as well as the oscillator provided for the alternating electrical energy driving the transducer may be located in the lower section 94 of the machine. The coin operated and cup dispensing mechanisms have not been shown for the sake of clarity, and it will be understood that any suitable form thereof may be used.

A modification of the mixing device of FIGURES 1A and 1B is shown in FIGURE 4. This embodiment is particularly suitable for applications where the transducer arrangement may be more suitably mounted in a vertical position. As shown therein, the vibratory element 40 is disposed so that its direction of vibration is aligned vertically. The powder and liquid to be mixed are introduced into the upper end of the plastic tube 102 which then is passed through the upper end of the vibratory element 40 at a slight angle below the horizontal. The tube 102 is then doubled back and again passed through the element 40 at a small angle, and thence to the output spout.

As can be seen, the constituents to be mixed are subjected to ultrasonic vibratory energy twice prior to being supplied to the output. By means of this arrangement, powders which are more difficult to dissolve may be adequately handled or, in the alternative, lower power transducers and smaller vibratory elements may be used. As in the case of the apparatus of FIGURES 1A and 1B, cavitation is induced in the liquid mixture as it passes through the tool producing the complete dispersion and degassing, as well as maintaining the inner walls of the plastic tubing relatively free from adhering material.

Where degassing of the liquid is a particular problem, such as where an additive ingredient may release large amounts of gas when put into solution, the arrangement shown in FIGURE 5 may be utilized. In this embodiment, the vibratory element 40 is shown as being provided with an elongated slot through its free end, rather than the circular hole as shown in the previous embodiments, although the latter may also be used. A funnel-shaped chamber 108 is brazed or otherwise rigidly fixed to the upper surface of the element 40 closely surrounding the opening or passage 106. The chamber is completely sealed except for a plurality of openings 110 in the upper surface and a larger central duct 112 through which the premixed powder and liquid is supplied. The passage 106 may be provided with a plastic liner as discussed in connection with FIGURES 1A and 1B, which extends below the tool to form an output spout 114.

The degassing chamber 108, being rigidly fixed to the element 40, will vibrate therewith in the direction as indicated by the arrows. As the premixed constituents

are supplied to the chamber, the agitation afforded within the chamber 108, which is relatively gentle as compared to the cavitation occurring during its transit through the passage 106, is effective to remove substantially all of the entrapped gases therein, which escape via the vents 110. Freedom from foam of the final reconstituted product is thereby assured.

Although obviously applicable to mixing of many different substances, the mixing apparatus of the present invention has found particular utility in connection with the reconstitution of powdered milk. Its speed of operation renders it well suited for use in automatic vending machines and by using ultrasonic energy to perform the mixing, the process can be carried out at low temperatures. Therefore, cold milk in bulk form may be dispensed.

In addition to the obvious advantages gained by the ability to store the milk in the form of a dehydrated powder, the present invention avoids the flavor and fluidity limitations inherent in presently known methods of reconstituting powdered milk. The cavitation action induced by the ultrasonic energy permits substantially complete dispersion of the milk powder in the liquid, thereby closely reproducing the flavor and consistency of the original product. It has been found that the sedimentation rate of the reconstituted product produced by the present apparatus is far below maximum acceptable levels set by the dry milk industry. This figure is arrived at by centrifuging the reconstituted product in graduated containers and noting the amount of sediment obtained thereby. The lower the amount of sediment, the more complete the dispersion. The reconstituted milk produced by the present invention is uniformly a clean drinking liquid, that is, no powder particles are detectable by the consumer while drinking, and the reconstituted produce closely resembles in texture the fluid milk product from which the powder is made. Moreover, the reconstitution is effected without the generation of foam which accompanies ordinary mechanical agitation methods.

While several embodiments of suitable mixing device according to the invention have been illustrated and described herein, it will be apparent that many other variations thereof will occur to those skilled in the art. Accordingly, the invention is not deemed to be limited except as set forth in the appended claims.

We claim:

1. Apparatus for producing a dispersion of a powder in a liquid comprising, transducer means adapted to convert alternating electrical energy into mechanical vibration at ultrasonic frequencies, a vibratory element coupled to said transducer means to be set into vibration thereby in a given direction, at least one opening extending through said element transversely to its direction of vibration, means to continuously supply said powder and liquid to said opening whereby they are subjected to vibratory energy and a dispersion produced as they pass through said element, and vent means in said supply means for enabling the escape of gases liberated from said powder and liquid by the vibratory energy applied thereto.

2. Apparatus for producing a dispersion of a powder in a liquid comprising, transducer means adapted to convert alternating electrical energy into mechanical vibration at ultrasonic frequencies, a vibratory element cou-

pled to said transducer means to be set into vibration thereby in a given direction, an opening extending through said element transversely to its direction of vibration, a smooth, nonporous lining for said opening, means to continuously supply said powder and liquid to said opening whereby they are subjected to vibratory energy and a dispersion produced as they pass through said element, and vent means in said supply means for enabling the escape of gases liberated from said powdered liquid by the vibratory energy applied thereto.

3. Apparatus according to claim 2 wherein said opening is circular and of a diameter relatively small with respect to the length thereof through said element.

4. A mixing device comprising a member adapted to be set into vibration in a given direction at ultrasonic frequencies, a plurality of passages of narrow width relative to their length extending through said member transversely to the direction of vibration, conduit means interconnecting said plurality of passages to form a single continuous flow path, input means for supplying the substances to be mixed to one end of said flow path, and output means coupled to the other end of said flow path for conducting the resultant mixture to a receptacle.

5. A mixing device comprising a member adapted to be set into vibration in a given direction at ultrasonic frequencies, a passage of narrow width relative to its length extending through said member transversely to the direction of vibration, a chamber rigidly mounted on said member to be vibrated therewith and having one end thereof in communication with said passage, at least one vent aperture in said chamber, means to supply the materials to be mixed to said chamber whereby the materials are degassed before passing into said passage for mixing, and output means coupled to the end of said passage opposite said chamber for conducting the resultant mixture to a receptacle.

6. Apparatus for producing a dispersion of a powder in a liquid comprising, transducer means for providing mechanical vibration at ultrasonic frequencies, a vibratory element coupled to said transducer means to be set into vibration thereby in a given direction, at least one opening extending through said element transversely to its direction of vibration, means for supplying said powder and liquid together to said opening whereby they are subjected to vibratory energy and a dispersion produced as they pass through said element, and vent means coupled to said supply means for enabling the escape of gases liberated from said powder and liquid by the vibratory energy applied thereto.

7. Apparatus according to claim 6 further comprising a smooth, non-porous liner for said opening.

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