Dec. 21, 1965 R. M. BROOMALL 3,224,744

VERTICAL MIXER CONSTRUCTION

Original Filed March 19, 1962 8 Sheets-Sheet 1

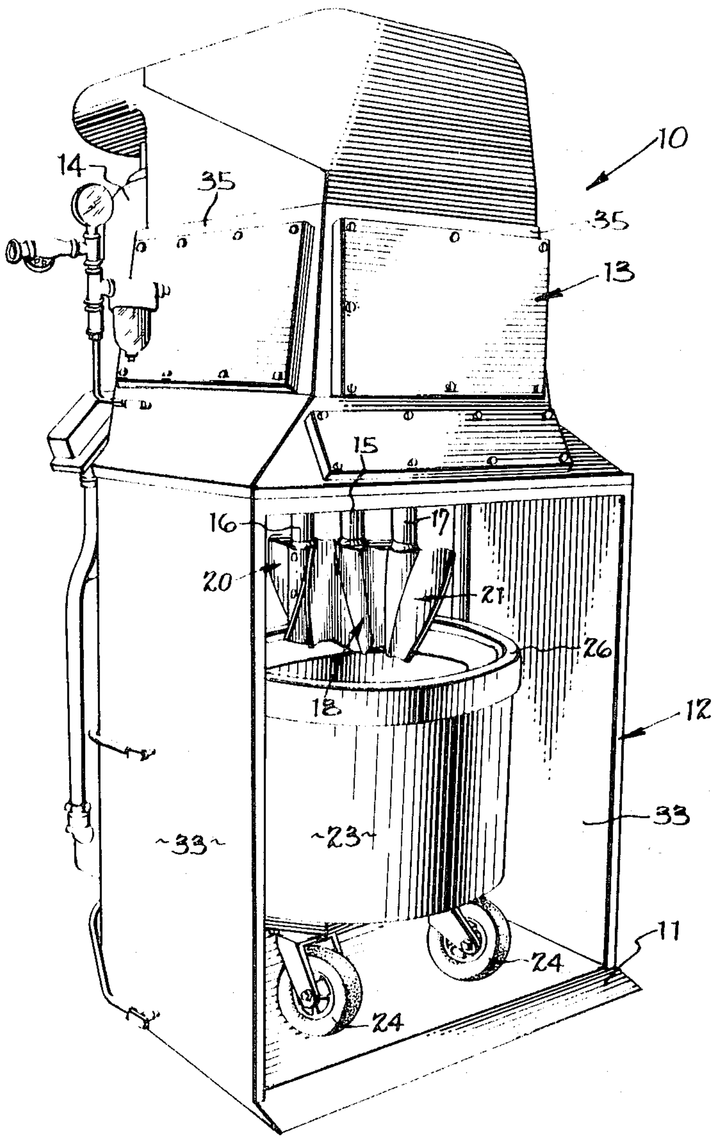

Fig. 1

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VERTICAL MIXER CONSTRUCTION

Original Filed March 19, 1962 8 Sheets-Sheet 2

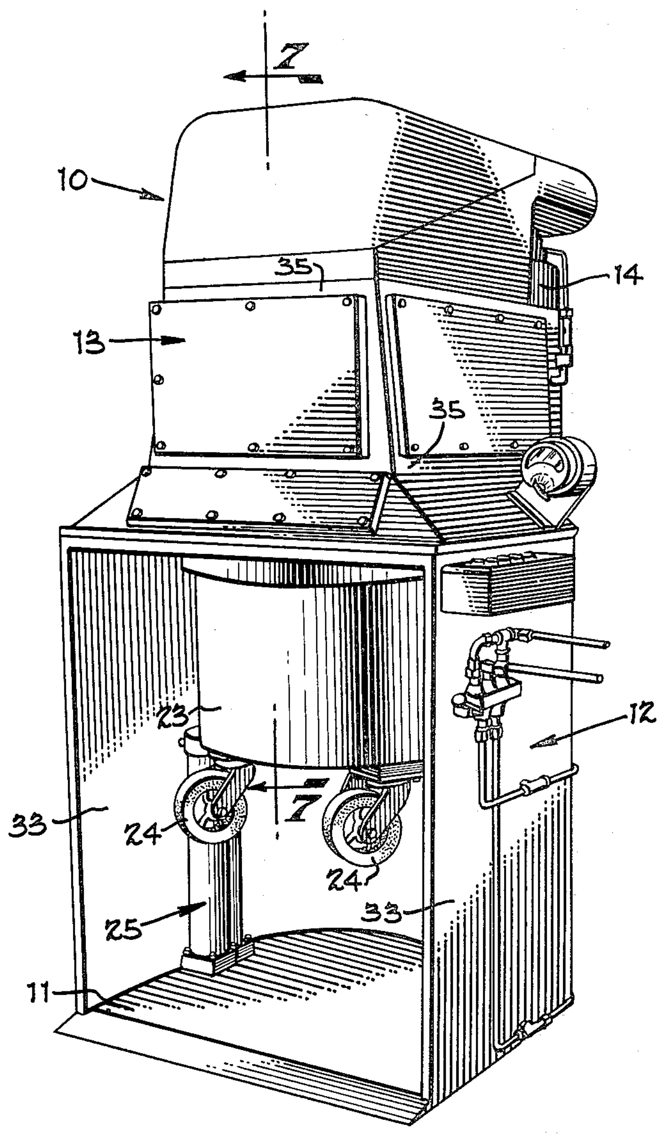

Fig. 2

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VERTICAL MIXER CONSTRUCTION

Original Filed March 19, 1962

8 Sheets-Sheet 3

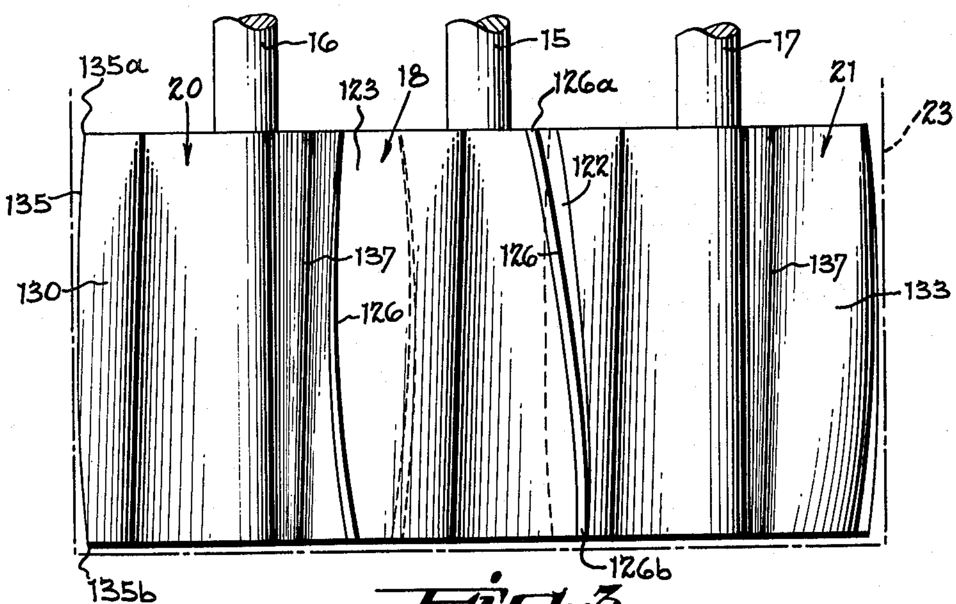

Fig. 3

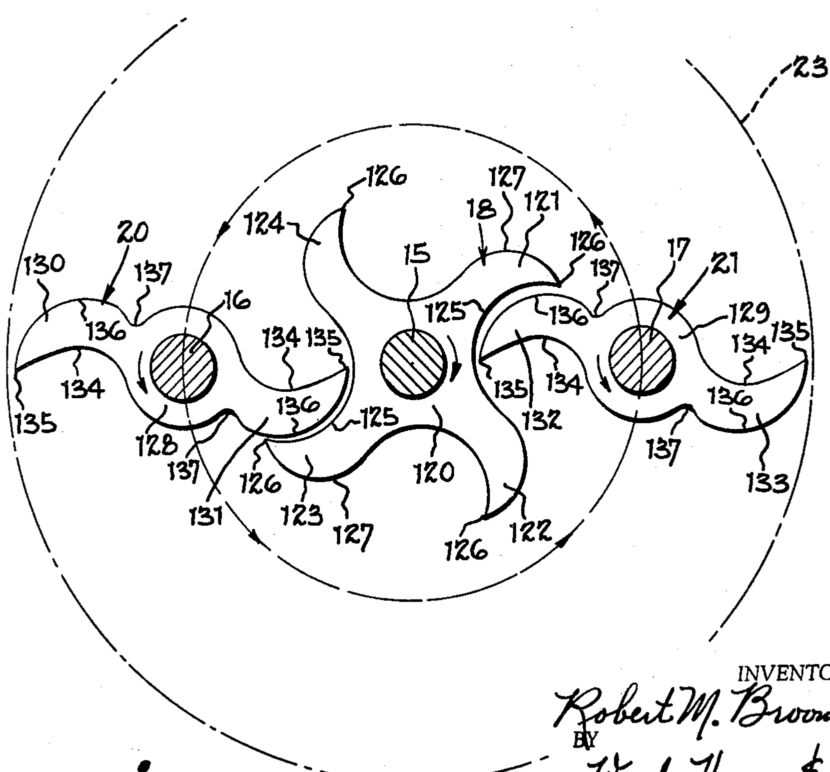

Fig. 4

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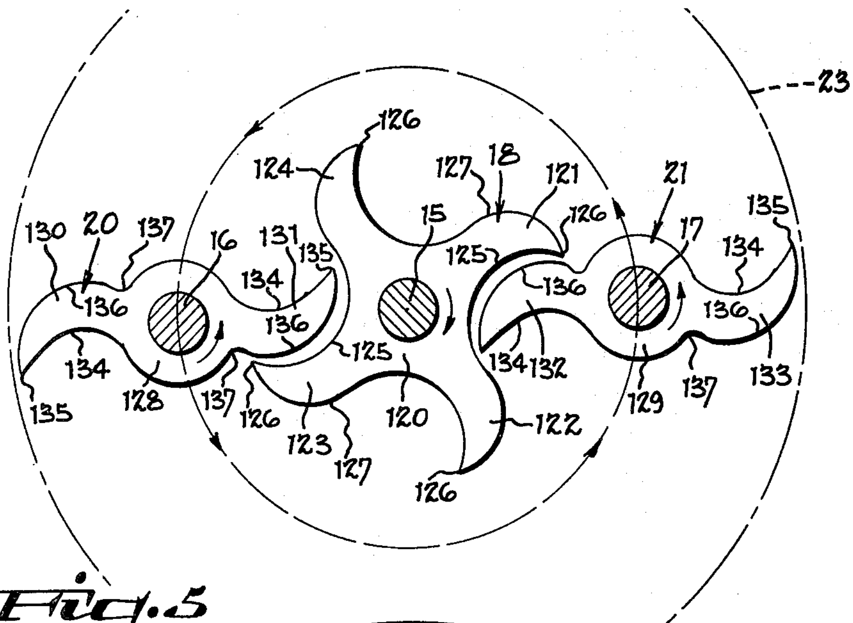

Fig. 5

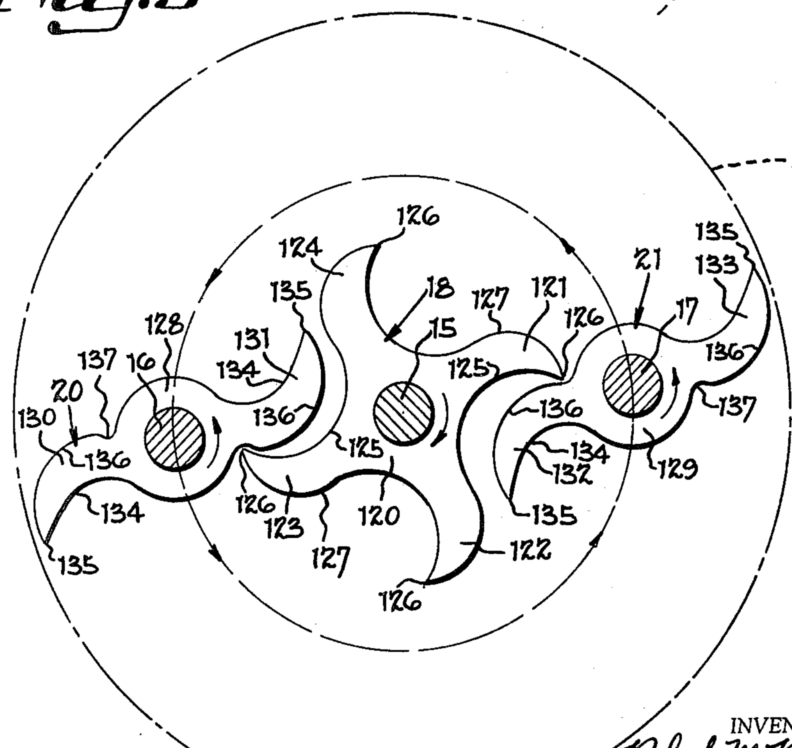

Fig. 6

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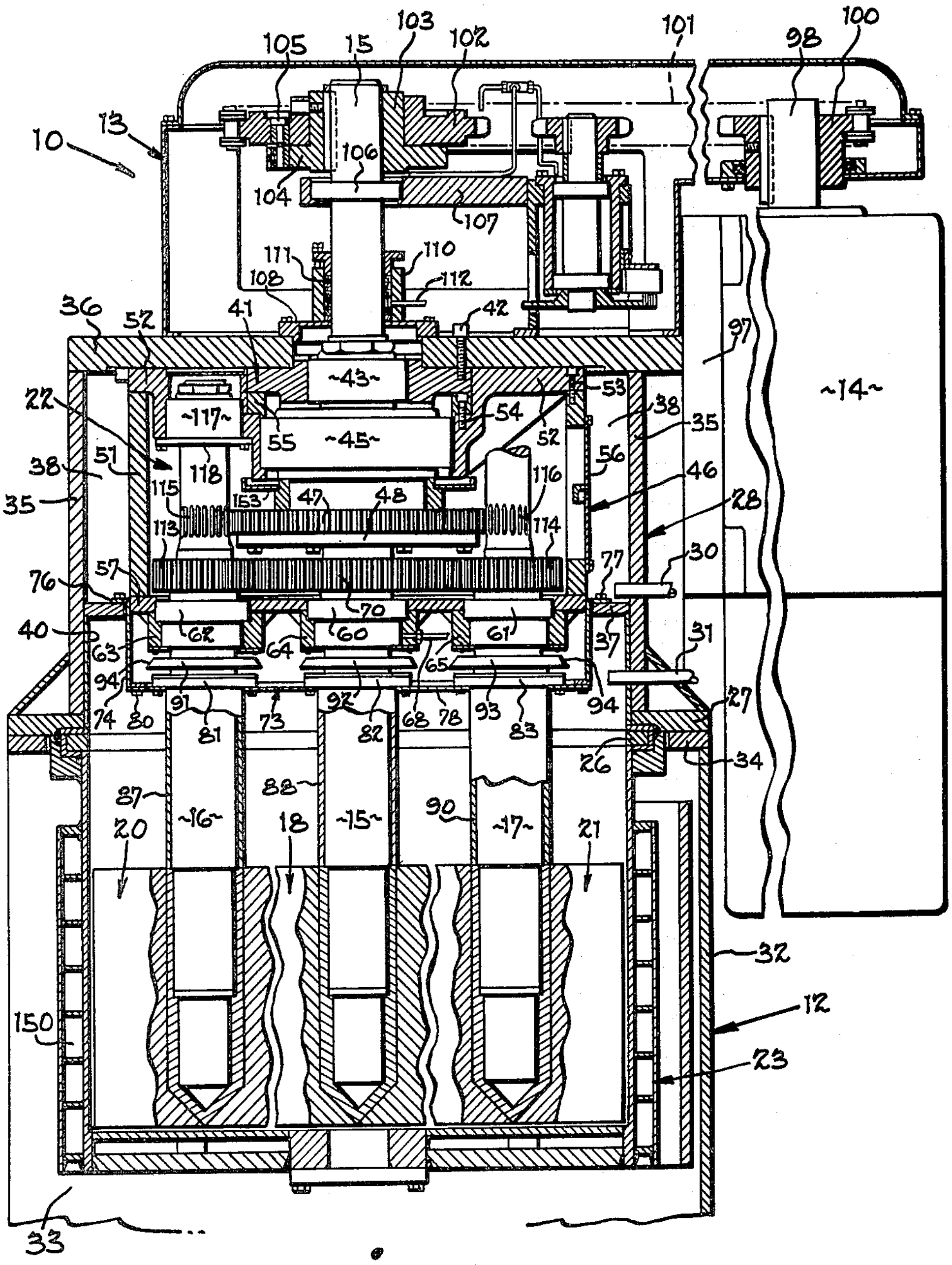

Fig. 7

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VERTICAL MIXER CONSTRUCTION

Original Filed March 19, 1962 8 Sheets-Sheet 6

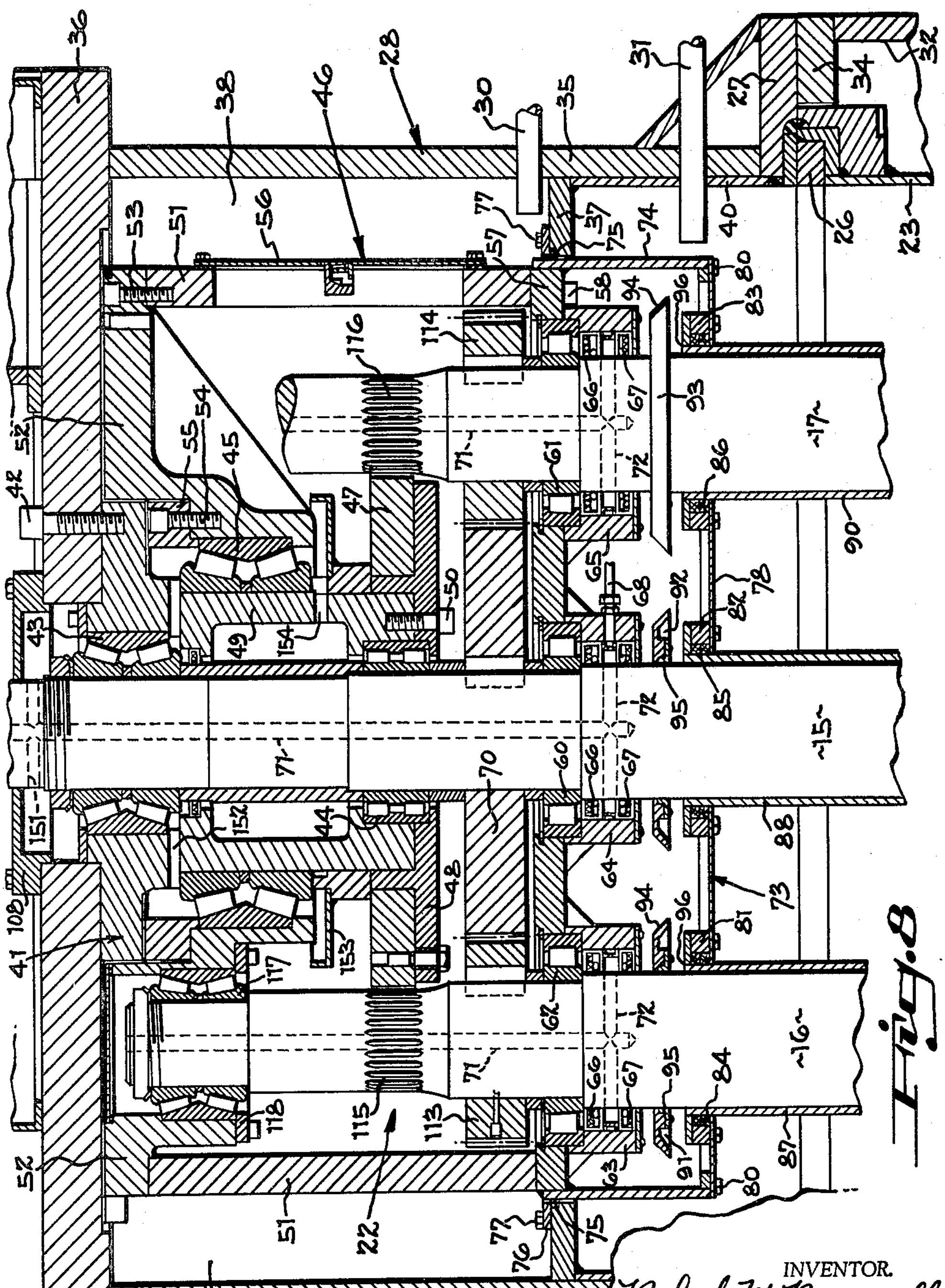

Fig. 8

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Original Filed March 19, 1962 8 Sheets-Sheet 7

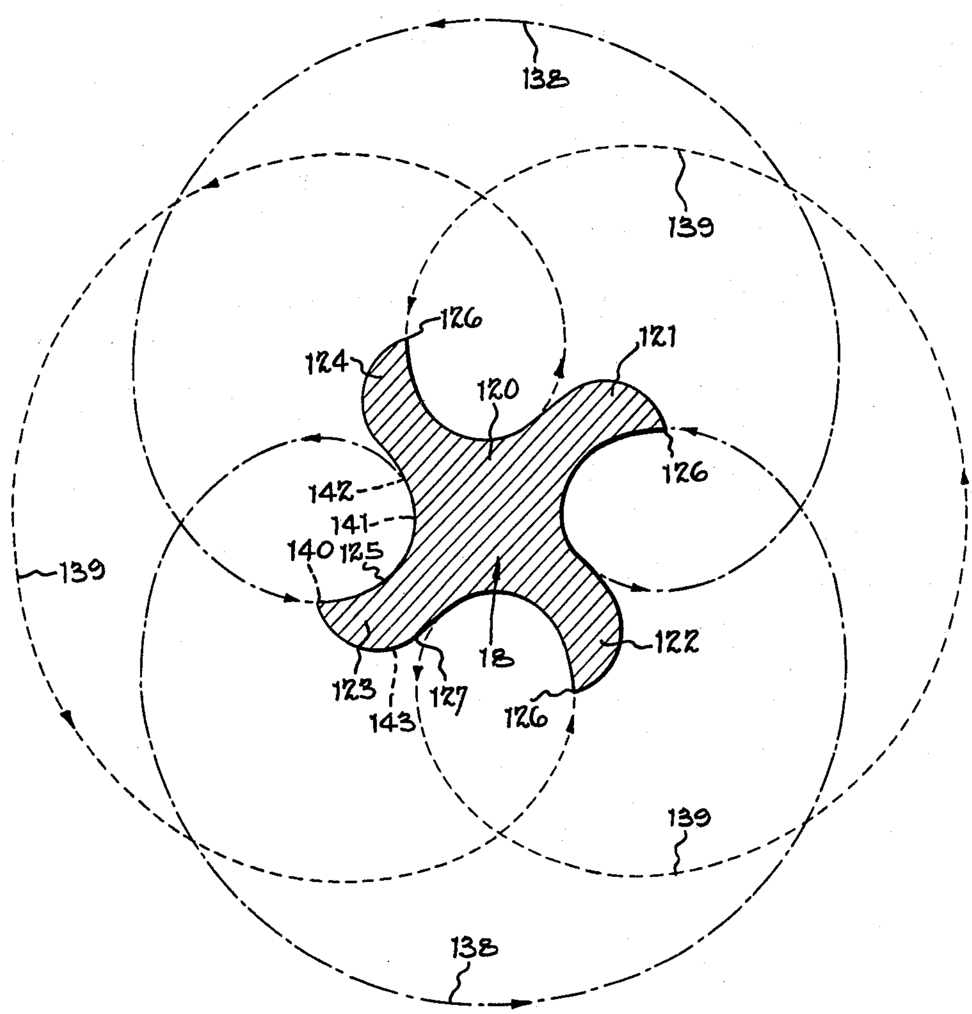

Fig. 9

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Original Filed March 19, 1962 8 Sheets-Sheet 8

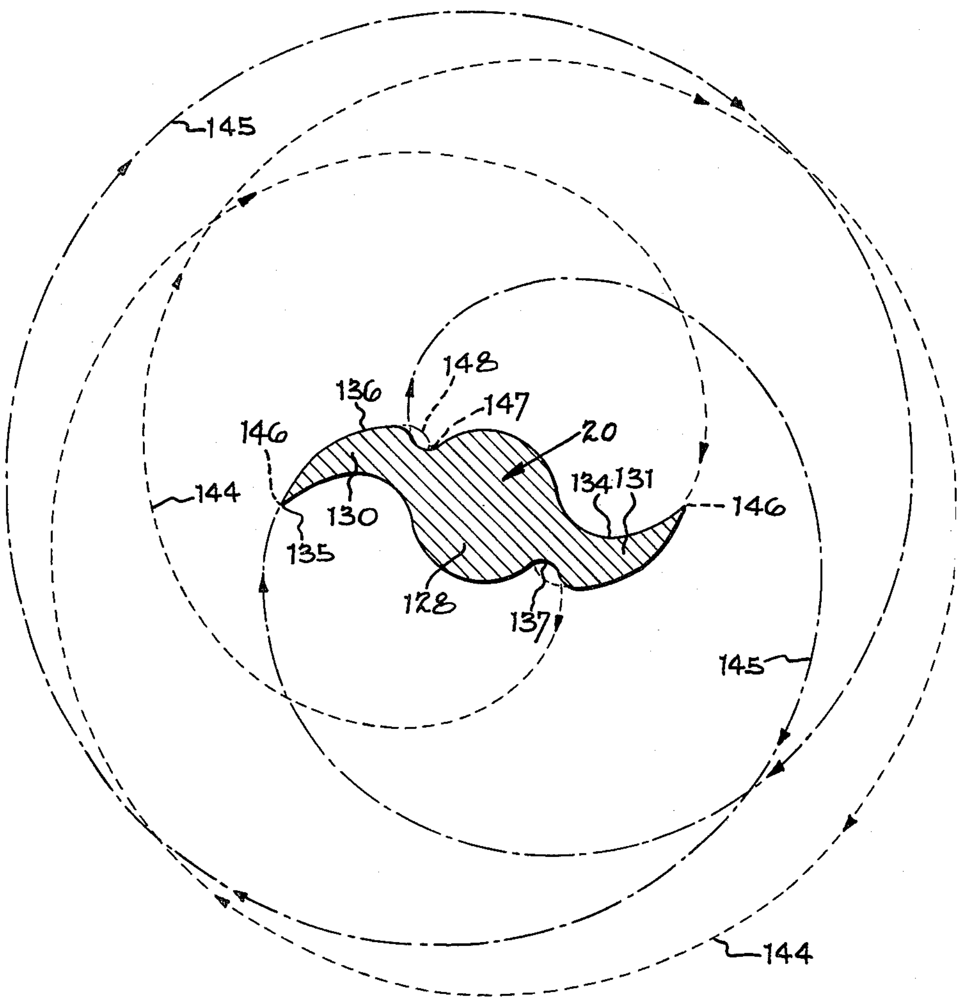

Fig. 10

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Patented Dec. 21, 1965

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3,224,744

VERTICAL MIXER CONSTRUCTION

Robert M. Broomall, Fort Thomas, Ky., assignor to The J. H. Day Company, a corporation of Delaware

Original application Mar. 19, 1962, Ser. No. 184,629. Divided and this application Mar. 30, 1964, Ser. No. 355,637

5 Claims. (Cl. 259—102)

The present application is a division of my copending application Serial No. 184,629, filed March 19, 1962, now United States Patent No. 3,151,847.

The present invention relates to mixers and is particularly directed to a novel vertical mixer in which material is subjected to both a thorough mixing action and a kneading action in which substantial shear forces are imposed upon the material.

There are at the present time in various chemical industries many materials which must be mixed in a very exacting manner under carefully controlled conditions. By way of example, in the processing of rocket propellant fuels, it is necessary to obtain a complete dispersion of an oxidizer, such as ammonium perchlorate ground into small particles in a plastic, resinous or elastomeric fuel material, such as polysulfide rubber. At the same time, it is necessary that there be effected a thorough mixing of various catalysts, inhibitors and other minor additives. Finally, it is necessary to obtain a maximum packing or densification of the particulate oxidizer material. The difficulties involved in mixing materials, such as a rocket fuel propellant, are compounded by the fact that the material must not be contaminated during the mixing as, for example, by contact with any oil from the mixer. Also, it is necessary that the material be mixed under a high vacuum.

The principal object of the present invention is to provide a mixer which is effective to mix chemicals with a mixing action which is substantially more efficient than that of any mixers available at the present time. Thus, the present mixer not only obtains an optimum mixture of the material but does so in only a fraction of the time previously required. By way of example, in one test run the present mixer was effective to complete a mixing operation in approximately thirty minutes which previously required six hours to perform on a conventional mixer. The effectiveness of the present mixer is due in part to the fact that the mixer combines two distinctly different types of action upon the material being mixed. In the first place, the mixer exerts a mixing action on the material so that the batch is made homogeneous and the various components of the mixture are completely dispersed throughout the entire mix. In the second place, the mixer exerts a kneading or squeezing action on the material so that the material is subjected to relatively high shear forces and any agglomerates are broken up and dispersed.

Another object of the present invention is to provide a mixer in which material can be subjected to a vigorous mixing action under a vacuum without contaminating the processed material with any oil or other lubricant from the mixing machine.

More particularly, the present invention is predicated in part upon the concept of providing a vertical mixer having three depending agiator shafts which carry cooperating agitator blades of a unique configuration. In the present mixer, the center agitator shaft rotates about a stationary axis and carries an agitator having four spiral arms extending outwardly therefrom. The two other shafts of the mixer move in a planetary movement around the center agitator shaft and at the same time rotate about their own axes. Each of these outer, or planetary shafts, carries an agitator blade having two spiral arm extending outwardly therefrom. The planetary shafts move planetwise in the reverse direction of rotation as that of the center shaft. In addition, these shafts rotate upon their own axes in the reverse direction to the direction of rotation of the center shaft.

The center agitator of the present mixer comprises four identical spiral arms extending outwardly from the hub of the agitator at substantially 90° intervals. Each of these arms includes a concave leading surface and a convex trailing surface joined by an outer tip. Each of the outer agitators includes two identical arms spaced 180° apart. Each of these outer arms also includes a concave leading surface and a convex trailing surface which meet at an outer tip. As is explained in detail below, the concave leading face of each of the center arms is configurated so that the cooperating tip of the outer arm sweeps along the concave leading face and is spaced from it only by a small uniform clearance distance, for example, an eighth of an inch. In a similar manner, the trailing face of the outer agitator blade is configurated so that the tip of the cooperating center blade sweeps over the trailing surface of the outer blade and clears that blade by a uniform clearance distance again of approximately an eighth of an inch. Additionally, the concave leading surface, the tip edge and the convex trailing surface of each of the arms of the center and outer blades is angulated with respect to the axis of the blades in the nature of a helix. Specifically, the helix angle of each of the blades extends upwardly and forwardly from the bottom of the blade to the top of the blade in the direction of rotation of the blade, the helix angle of the center blade being substantially one-half that of the outer blades. For example, in one preferred mixer the center agitator has a helix angle of 15° while the outer blades have a helix angle of 30°.

As the blades rotate, the arms of the outer blades first sweep along the rim of the bowl and force material inwardly toward the center of the bowl. During the inward portion of its movement, the tip of each outer agitator blade in turn passes adjacent to the tip of one of the arms of the center blade. The tip of the arm of the outer blade then passes inwardly and sweeps along the leading surface of the center blade arm. At the same time, the tip of the arm of the center blade sweeps along the trailing surface of the same arm of the outer blade. As the blades intermesh, the entire leading surface of the center blade arm and the trailing surface of the outer blade arm extend substantially parallel to one another and are spaced only a small distance apart. Since these surfaces of substantial area are moving transverse to one another, a very effective shearing and kneading action is exerted upon the material being processed. At the same time, the helix angle of the blades forces the material downwardly toward the bottom of the container from the top which contributes to the efficiency of the kneading and mixing action.

In accordance with the present invention, the upper ends of the outer shafts and the drive mechanism for rotating the shafts and the center shaft are mounted within a rotatable head. This head assembly is enclosed by a transverse bottom wall which also carries a lubricating pump. The entire lower portion of the head above the bottom wall functions as an oil sump and the lubricating pump pumps the oil from this sump up over the various bearings and gears in the head assembly. This construction requires that seals be provided at the transverse wall around each of the three agitator shafts.

One aspect of the present invention involves the provision of a dry well beneath this transverse wall for preventing any oil which might leak through these seals from contaminating the material being mixed. Specifically, in accordance with the present invention, the dry well comprises a bottom wall and a peripheral skirt which depends from the main transverse wall of the head assembly. The bottom wall of the dry well also includes sealing gaskets which surround each of the agitator shafts. Each of the agitator shafts carries a deflector plate above these sealing gaskets, the deflector plates being effective to prevent any oil from dropping directly onto the sealing gaskets. Thus, any oil which may leak through the main seals carried by the transverse plate must accumulate to a substantial depth on the bottom wall of the dry well before the oil could possibly come into contact with the set of gaskets carried by the dry well bottom.

Another feature of the present mixer construction which helps to prevent contamination of the mixed material by lubricating oil, or the like, is the provision of a transverse wall carried by the vacuum shroud which effects a seal with the annular wall of the skirt assembly. In accordance with the present invention, vacuum lines are connected to the shroud assembly both above this transverse partition and below the transverse partition. The line below the transverse partition is effective to draw a vacuum upon the material being processed. The vacuum line above the transverse partition is effective to draw a vacuum on the head so that no pressure differential is created across the various seals and joints, minimizing the possibility of oil leakage.

These and other objects and advantages of the present invention will be more readily apparent from a consideration of the following detailed description of the drawings illustrating one preferred form of the invention.

In the drawings:

FIGURE 1 is a perspective view of a mixer of the present invention showing a mixer bowl in position to be elevated up into the mixing position.

FIGURE 2 is a perspective view of the mixer shown in FIGURE 1 illustrating the mixer bowl in the mixing position.

FIGURE 3 is an elevational view of one set of mixing blades of the present invention.

FIGURE 4 is a diagrammatic top plan view of the mixer blades as the blades approach the position of maximum intermesh.

FIGURE 5 is a diagrammatic top plan view of the mixer blades showing the blades at a slightly later point in the operating cycle.

FIGURE 6 is a top plan schematic view showing the position of the mixer blades at a still later time as the cooperating blades start to separate from one another.

FIGURE 7 is a vertical cross sectional view taken along line 7—7 of FIGURE 2.

FIGURE 8 is an enlarged cross sectional view of the head of the mixer.

FIGURE 9 is a cross sectional view of the center agitator blade showing the relationship between the configuration of this blade and the locus of movement of the tips of the outer agitator blades relative to the center blade.

FIGURE 10 is a cross sectional view of an outer agitator blade showing the relationship of this blade to the locus of movement of tips of the center blade relative to the outer agitator blade.

One preferred form of mixer **10** constructed in ac-

cordance with the principles of the present invention is shown in FIGURE 1. As there shown, the mixer comprises a base **11**, a lower housing section **12** and an upper housing, or head enclosing housing **13**. A motor **14** is mounted rearwardly of upper housing **13**. Mixer **10** includes three depending vertical shafts, a center shaft **15** and two outer, or planetary shafts, **16** and **17**. Each of the shafts **15**, **16** and **17** has a mixer blade **18**, **20** and **21** respectively secured thereto.

Mixer blade **18**, mounted upon center shaft **15**, has four spiral arms extending outwardly therefrom, while each of the blades **20** and **21** mounted upon outer shafts **16** and **17** has two spiral arms extending outwardly. Housing **13** encloses a drive mechanism **22** effective to rotate center shaft **15** about a stationary axis. This same drive mechanism is effective to drive the shafts **16** and **17** in a planet-wise movement about the center shaft **15**. At the same time, each of the shafts **16** and **17** is rotated about its own axis.

The material being mixed is carried in a bowl **23**. In the embodiment shown, bowl **23** is rolled into position beneath the mixing head by means of wheels **24**. Once the bowl is positioned beneath the agitator shafts and mixer blades, the bowl is elevated and supported by means of a bowl elevating mechanism indicated generally at **25**. When the bowl is supported in the mixing position, the upper rim **26** of the bowl seats against a lower shoulder **27** formed as part of a shroud assembly **28** mounted within upper housing member **13**. Two vacuum lines **30** and **31** communicate with the vacuum shroud assembly so that a vacuum can be drawn both upon the mixing bowl **23** and the head drive **22**.

The details of construction of the mixer head and housing are best shown in FIGURES 7 and 8. As is there shown, lower housing **12** comprises a rear panel **32** and side panels **33** joined to upper inwardly extending flanges **34**. These flanges **34** in turn abut flanges or shoulders **27** formed as part of shroud assembly **28**. The shroud assembly includes upstanding side walls **35** which are joined at their lower end in airtight relationship to flange **27** and at their upper edge to top plate **36**. An annular divider plate **37** extends transverse across shroud **28** at a point spaced upwardly from flange **27**. As is explained in detail below, this ring functions to prevent the material being mixed from contaminating the lubricating oil by providing a seal between the space below the mixer head, and the mixer head annular space **38**. The transverse ring is preferably made of stainless steel and together with liner members **40** made of stainless steel also functions to keep the material from being contaminated by the shroud wall or head assembly.

The top plate, or platen **36**, carries a center post member **41**. This center post member depends from the platen and is secured thereto as by means of bolts **42**. Center post **41** is a rigid member which has an enlarged vertical bore formed therein for receiving center shaft **15**. Center post **41** supports an upper set of bearings **43** and a lower set of bearings **44** for rotatably journalling the center shaft. Center post **41** also includes an annular wall section **49** which supports a main load bearing **45** for rotatably journalling and supporting head assembly **46**. In addition to these elements, center post **41** also carries a stationary sun gear **47**. This gear surrounds the center post and is held in place by means of a large retaining ring **48** which is bolted to center post **41** as by means of bolts **50**.

Head assembly **46** includes a heavy, cylindrical upstanding side wall member **51**. This member is bolted to a rotatable top plate **52** as by means of bolts **53**. Rotatable top plate **52** in turn includes an inner cylindrical flange for engaging main load bearings **45**. Top plate **52** is bolted as by means of bolts **54** to a thrust ring **55** which also engages main load bearings **45**.

An access door **56** is bolted over an opening formed in cylindrical side wall **51**. The lower end of wall **51** supports a main transverse plate **57** of the head assembly, the transverse plate being secured to cylindrical wall **51** in any suitable manner, such as by means of bolts **58**. Transverse wall **57** has a center opening therein for receiving a bearing **60** which is rotatably journalled upon center agitator shaft **15**. Transverse wall **57** also carries bearings **61** and **62** which rotatably journal outer agitator shafts **16** and **17**.

Cylindrical enclosures **63**, **64** and **65** forming part of the lubrication system are welded or otherwise secured to the undersurface of transverse wall **57** surrounding each of the agitator shafts **15**, **16** and **17**. Each of these lubrication cylinders houses an upper sealing ring **66** and a lower sealing ring **67** spaced from one another. A tube, such as tube **68**, shown in FIGURE 8 is interconnected to the annular space between the upper and lower gasket rings of each of the enclosures **63**, **64** and **65**. Tubes **68** (the tubes joined to enclosures **63** and **65** are not shown) are connected to the outlet port of a gear driven pressure pump. This pump (not shown) is mounted upon the upper surface of the transverse wall **57**. The pump includes a gear which meshes with drive gear **70** which is carried by center agitator shaft **15** and is keyed thereto for rotation with that shaft.

Each of the agitator shafts **15**, **16** and **17** is provided with a vertical bore **71** and transverse bores **72** in communication with the annular space in enclosures **63**, **64** and **65** respectively. Oil introduced through tubes **68** enters the chambers **63**, **64** and **65** and flows from these chambers through transverse bores **72** and vertical bores **71** to lubricate the various bearings and gears of the head drive in a manner explained in detail below.

Head assembly **46** also includes a dry well, or oil trap **73**. Well **73** comprises a depending cylindrical skirt member **74** which is welded or otherwise secured to cylindrical wall **51** of the head assembly and extends downwardly beneath transverse wall **57**. The upper end of skirt **74** revolves within transverse ring **37**. A seal is effected between skirt **74** and this ring by means of an annular gasket **75** which is clamped in place by a retaining ring **76** bolted to transverse ring **37** as by means of bolts **77**.

Well **73** also includes a bottom plate **78**, preferably formed of stainless steel. This bottom plate is secured to skirt member **74** in any suitable manner, such as by means of bolts **80**. Bottom wall **78** carries three gasket clamping rings **81**, **82** and **83** which are bolted or otherwise secured to the bottom wall surrounding agitator shafts **15**, **16** and **17**. Suitable gaskets **84**, **85** and **86** are held by these rings in sealing engagement with the peripheries of stainless steel sleeves **87**, **88** and **90** which are fixed to agitator shafts **15**, **16** and **17** respectively.

As is best shown in FIGURE 8, each of the agitator shafts **15**, **16** and **17** carries a deflector plate disposed in the space above gaskets **84** and their retaining rings and below cylindrical housings **63**, **64** and **65**. Each of the deflector rings **91**, **92** and **93** is of a diameter greater than the diameter of gasket retaining rings **81**, **82** and **83** and includes a downwardly beveled outer edge **94**. Deflector rings **91**, **92** and **93** are bolted to a radial mounting flange **95** which is welded or otherwise secured to each of the agitator shafts **15**, **16** and **17**. As is explained in detail below, the function of the deflector rings is to prevent any oil leaking past seals **66** and **67** from dropping into the space between the agitator shafts and gaskets **84**, **85** and **86** and possibly leaking through these gaskets into the interior of the bowl **23** to contaminate the material being processed. Rather, any small amount of oil dropping onto the deflector plates drops directly onto the bottom plate **78** of the well. Since this bottom of the well is a substantial distance below the juncture **96** between the rotating agitator shafts and the retaining rings **81**, **82** and **83**, a considerable volume of oil must accumulate in the well before there is a possibility that any of the oil can leak past gaskets **86** and into the mixing bowl.

Agitator shafts **15**, **16** and **17** are driven from an electrical motor **14** mounted upon a suitable frame structure **97** secured to the mixer housing. The output shaft **98** of motor **14** carries a drive pinion **100** which meshes with a drive chain **101**. This chain in turn meshes with a driven pinion **102** mounted upon a sleeve **103** which is keyed to the upper end of agitator shaft **15**. Gear **102** is carried by a radial flange **104** formed upon sleeve **103** and is connected in driving relationship with the sleeve by means of a shear pin **105**. The upper end of shaft **15** is journalled in a bearing **106** carried by a frame member **107**. Shaft **15** passes downwardly through an opening provided in a plate **108** bolted over an opening in top platen member **36**. Plate **108** carries a sleeve **110** which surrounds agitator shaft **15** and carries a plurality of sealing rings **111**. As is shown in FIGURE 7, the upper and lower rings are spaced from one another and are connected to a vacuum line **112**.

Shaft **15** is driven in a clockwise direction, as viewed in FIGURES 4, 5 and 6. The center agitator shaft carries a main drive gear **70** which is keyed to the shaft. This gear in turn meshes with driven gears **113** and **114** which are keyed to the outer agitator shafts **16** and **17**. Each of the agitator shafts **16** and **17** also has a second set of gear teeth **115** and **116** machined thereon for engagement with stationary sun gear **47**.

The upper end of each of the agitator shafts **16** and **17** is rotatably journalled in a thrust bearing **117** supported in a suitable opening formed in rotatable top plate **52** of the head assembly. The bearings are held in place by retaining rings **118** which are bolted to plate member **52**. A thrust ring is threaded over the end of each of the agitator shafts **16** and **17** for engagement with bearings **117**. As was explained above, each of the agitator shafts is also supported by a bearing **61**, **62** carried by main transverse wall **57** of the head assembly. By virtue of the gear drive just explained, agitator shafts **16** and **17** are driven in a planet-wise movement counterclockwise about center agitator shaft **15** as viewed in FIGURE 4. At the same time, each of the agitator shafts **16** and **17** is rotated about its own axis in a counterclockwise direction at a rate of rotation twice that of the center agitator shaft. The rate of orbital rotation of the shafts **16** and **17** varies but is such that the top speed of the agitator blades **20** and **21** does not substantially exceed thirty-four hundred inches per minute. This value has been empirically determined to be the approximate upper limit of tip speed which gives effective mixing action.

Center agitator shaft **15** carries agitator blade **18**. Blade **18** is mounted upon the lower end of shaft **15** in any suitable manner, for example by press fitting the blade over the end of the shaft and then passing a transverse pin (not shown) through aligned openings in the blade and shaft. Outer agitator shafts **16** and **17** carry blades **20** and **21** which are mounted upon the ends of the respective agitator shafts in the same manner.

Agitator blade **18** includes a hub section **120** and four outwardly extending spiral arms **121**, **122**, **123** and **124**. Each of these arms is identical with arm **123** so only that arm will be described in detail. Arm **123** includes a leading edge **125** presenting a generally concave face to the process material as the arm is advanced. The arm includes an outer tip **126** and a convex trailing face **127**. The leading surface of arm **123** merges smoothly with the trailing surface of arm **124** to form a continuous surface of generally S-shaped configuration. In a similar manner, the trailing edge of arm **123** merges with the leading edge of arm **122** in a surface of generally S shape. As is shown in FIGURE 4, the four arms **121**, **122**, **123** and **124** are equispaced from one another so that the arms are approximately 90° apart. It is to be understood that the semi-diagrammatic view of FIGURE 4 shows the shape of the blade **18** as it would appear in a transverse cross section. In fact, each of the arms **121**, **122**, **123** and **124** is helical in configuration, the helix advancing from the top to the bottom of the agitator blade in the direction of the blade rotation. A preferred helix angle is approximately 15°. As is shown in FIGURE 3, the tip portion **126*a*** at the top of blade **122** is approximately 15° ahead of the tip portion **126*b*** at the bottom of the blade. Each of the arms **121**, **122**, **123** and **124** embodies this same 15° helix angle.

Center agitator blade **18** cooperates with two planetary blades **20** and **21**. The blades **20** and **21** include hub sections **128–129** which are mounted upon the ends of shafts **16** and **17** in the same manner that agitator **18** is mounted on the lower end of shaft **15**. Each of the agitator blades **20** and **21** comprises two arms **130**, **131**, **132** and **133**. Blades **20** and **21** rotate in a counterclockwise direction as is shown in FIGURE 4 at a rate twice the rate of rotation of blade **18**. At the same time, the shafts **16** and **17**, which carry blades **20** and **21**, move counterclockwise in a planetary movement around center shaft **15**.

Each of the blades **20** and **21** is identical so that only blade **20** will be described in detail. The arms **130** and **131** of blade **20** are disposed along a substantially diametral line. Each of these arms comprises a leading surface **134** which presents a generally concave face to the material as the blade advances. Each arm also encloses a tip **135** at the outer edge of the leading surface and a convex trailing surface **136**. As shown in FIGURE 4, there is a slight undercut portion **137** at the juncture of the trailing edge **136** and hub section **128**.

Again, the configuration of agitator blades **20** and **21** in FIGURE 4 represents a transverse sectional view through the blades. In fact, as is shown in FIGURE 3, each of the agitator blades is helical in shape. The helix angle of these blades again extends from the bottom to the top in the direction of advancement of the blades. This helix angle is substantially twice the helix angle of the center blade **18**. Thus, as is shown in FIGURE 3, the top point **135*a*** of tip **135** is approximately 30° ahead of the lower edge of the tip **135*b***. It is to be understood that each of the arms **130**, **131**, **132** and **133** has the same helix axis.

During operation of the mixer, each of the tips **135** of arms **131** and **132** is brought into proximity with tip **126** of center agitator arms **123** and **121** respectively. Due to the fact that the agitators **20** and **21** are rotating at twice the speed of center agitator **18** and at the same time are moving in a planet-wise movement about the center agitator, tips **135** sweep the leading surfaces **125** of arms **123** and **121**. They also sweep a portion of the trailing surfaces of arms **124** and **122** as is indicated in FIGURE 5. At the same time, tips **126** of arms **123** and **121** of the center agitator sweep along the trailing surfaces **136** of arms **131** and **132**. During this movement, the trailing surface **136** and the leading surface **125** of the outer arms and center agitator arm respectively extend generally parallel to one another and are moving transverse to one another at a distance of approximately one-eighth of an inch so that a very effective kneading action in which the material is subjected to substantial shear forces is achieved. When the adjacent blade surfaces separate as is shown in FIGURE 6, tip **135** of the blade **130** starts to move outwardly toward the liner of bowl **23**. As it moves outwardly it passes within an eighth of an inch or so of the bowl and then starts to move inwardly again. Simultaneously, the tip of arm **130** sweeps the leading surface of arm **122** and the tip of arm **133** sweeps the leading face of arm **124**. Subsequently, the tip of arm **131** sweeps the leading face of arm **121** while the tip of arm **132** sweeps the leading face of arm **123**.

The manner in which the exact configuration of the arms of center agitator **18** is obtained can best be seen in FIGURE 9. FIGURE 9 shows a sectional view through the agitator blade together with two lines **138** and **139**. Line **138** represents the locus of movement of tip **135** of arm **131** relative to the center agitator **18**. The line **139** represents the locus of the tip of arm **130** relative to center agitator **18**. As can be clearly seen in FIGURE 9, the locus of tip **135** of arm **131** is such that it moves inwardly along the leading surface of arm **123** and a portion of the trailing surface of arm **124** and then moves outwardly toward the wall of the bowl. Subsequently, the tip moves inwardly along the leading surface of arm **121** and a portion of the trailing surface of arm **122**. Thereafter, the tip again moves outwardly toward the surface of the bowl before it starts to move inwardly to again sweep the surface of arm **123**.

The configuration of center agitator **18** is determined by plotting this locus and then conforming the surface of the agitator arms to the locus (allowing only for a predetermined clearance, for example one-eighth of an inch) from the time that the locus of the tip **135** moves within the radius of the arms **123** etc. of center agitator **18** as at point **140** until the tip **135** has advanced through its point of deepest penetration as at point **141** and has returned a substantial distance out toward the radius of arm **123** as indicated at point **142**. While the exact shape of the convex bulge **143** in trailing edges **127** is not critical, I have empirically determined that by providing an exaggerated bulge at this point a slightly improved mixing action is achieved.

The design of the planetary blades **20** and **21** is best shown in FIGURE 10. This figure shows a planetary blade **20** and two lines **144** and **145** which represent the locus of movement of tips **126** of center agitator arms **121**, **122**, **133** and **124** relative to the agitator blade **20**. Specifically, line **144** represents the locus of tips **126** of arms **123** and **121**, while line **145** represents the locus of tips **126** of arms **122** and **124**.

As is shown in FIGURE 10, the critical surface on the outer agitator blades is the trailing surface **136** on each of the arms. The contour of this surface is determined by the locus of tip **126** from the time that it reaches the maximum radius of arm **131** as at point **146** until the locus of point **126** passes inwardly to its point of deepest penetration adjacent to hub **128** as at point **147**, makes a loop indicated at **148** and again crosses the locus line and coninues to move outwardly. Again, of course, the desired clearance distance is left, in this case an eighth of an inch, between the locus of tip **126** and the trailing surface **136** of the agitator arm. It should be noted that the loop **148** in the locus of point **126** gives rise to the necessity of undercut portion **137** at the juncture of the trailing surface **136** and hub portion **128**.

FIGURE 7 shows the cooperative relationship of blades **18**, **20** and **21** within bowl **23**. It is to be understood that the bowl is held in position in any suitable manner. For example, the outer rim of the bowl may be provided with downwardly opening recesses for receiving transverse pins carried by the piston rods of hydraulic pistons (not shown) effective to lift the bowl and hold it in airtight engagement with flange **27**. With the bowl in this position, a vacuum is drawn on the bowl through tube **31**. In a similar manner a vacuum is drawn on the upper head through line **30**, these lines being connected to any suitable vacuum pump.

In operation, a bowl filled with material to be mixed is raised into position as shown in FIGURE 2. Thereafter, a vacuum is drawn on lines **30** and **31** and on tube **112**. If necessary or desirable, a liquid may be circulated through a cooling jacket **150** fitted around bowl **23** so that the process material can be kept not only under the desired pressure but also at a desired temperature. When motor **14** is energized, it is effective to rotate center shaft **15** through drive chain **101**. As the center shaft **15** rotates, it carries center agitator **18** with it, rotating that agitator in a clockwise direction.

At the same time, agitator shafts **16** and **17** are driven from main gear **70**. These shafts thus rotate about their own axes. However, the engagement of gears **115** and **116** carried by these shafts with stationary sun gear **47** also causes the head assembly **46** and agitator shafts **16** and **17** to be moved in a counterclockwise direction at a rate of slightly in excess of one-half times the rate of rotation of the center agitator. As was explained previously, the planetary agitators **20** and **21** rotate in a counterclockwise direction at a rate of speed twice that of the center agitator **18**. These outer agitators are effective to scrape the outer surface of the bowl and to force material inwardly. The material adjacent the center of the bowl is subjected to a very high shearing and kneading force as the leading surface of the center agitator arms pass parallel and closely adjacent to the trailing sufaces of the outer agitator arms. At the same time, the helix angles of the agitators force material from the top of the container downwardly. Thus, the material is thoroughly mixed and kneaded. At the conclusion of the mixing operation, the vacuum is removed from lines **30** and **31** and the bowl is lowered to a position in which it can be removed from the mixer.

During operation of the mixer, the various gears and bearings are lubricated by a system which includes a gear driven pump (not shown) mounted upon transverse plate **57**. It is to be understood that the space above plate **57** functions as an oil sump so that the pump has an inlet line disposed just above the plate. The pump supplies oil under pressure through tubes **68** to cylindrical housing sections **63**, **64** and **65**. Oil flows from these sections through transverse bores **72** and vertical bores **71** in the three agitator shafts. The oil is discharged from the top ends of bores **71** of agitator shafts **16** and **17** onto upper bearings **117**. The oil drops from these bearings to lubricate gears **115**, **116** and sun gear **47**. Similarly, oil flows from vertical bore **71** and center shaft **15** outwardly through a transverse bore **151** formed in that shaft just below plate **108**. Oil flowing outwardly through this upper transverse bore drops over bearing **43** and flows outwardly through transverse ports **152** and flows over bearing **45**. Oil dropping from bearing **45** is caught by annular plate **153** and flows inwardly through ports **154**. The oil then drops downwardly over lower bearings **44**.

From the foregoing discussion of the general principles of the present invention and the above description of a preferred embodiment, those skilled in the art will readily comprehend various modifications to which the invention is susceptible. For example, it is obvious that four planetary shafts and agitator blades similar to those shown could be employed is desired. Therefore, I deside to be limited only by the scope of the following claims.

Having described my invention, I claim:

1. A vertical mixer comprising a vacuum shroud having a lower shoulder adapted for airtight engagement with the rim of a bowl, a rotatable mixing head disposed within said vacuum shroud above said shoulder, a center shaft depending from said mixing head, a planetary shaft depending from said mixing head, an electric motor mounted upon said mixer, means interconnecting said motor and said center shaft for rotating said shaft in a first direction, means interconnecting said first shaft and said planetary shaft for rotating said planetary shaft about its own axis in the opposite direction from the rotation of said center shaft and for simultaneously moving said planetary shaft planet-wise about said center shaft, first means for drawing a vacuum upon the interior of said bowl, sealing means extending inwardly from said shroud to form a transverse seal between said shroud and said mixing head, and second means for drawing a vacuum above said sealing means, whereby the pressure between said bowl and head is equalized.

2. A vertical mixer comprising a vacuum shroud having a lower shoulder adapted for airtight engagement with the rim of a bowl, a rotatable mixing head disposed within said vacuum shroud, a center shaft depending from said mixing head, a planetary shaft depending from said mixing head, an electric motor mounted upon said mixer, means interconnecting said motor and said center shaft for rotating said shaft in a first direction, means interconnecting said first shaft and said planetary shaft for rotating said planetary shaft about its own axis in the opposite direction from the rotation of said center shaft and for simulaneously moving said planetary shaft planetwise about said center shaft, said mixing head including a transverse lower wall, lubricating means disposed above said wall, sealing means carried by said wall for forming a seal between said wall and said shafts, and a dry well depending from said mixing head and including a transverse bottom wall carrying second sealing means in engagement with said shafts, and deflector plates mounted upon said shafts intermediate said first and second sealing means.

3. A vertical mixer comprising a vacuum shroud having a lower shoulder adapted for airtight engagement with the rim of a bowl, a rotatable mixing head disposed within said vacuum shroud, a center shaft depending from said mixing head, a planetary shaft depending from said mixing head, an electric motor mounted upon said mixer, means interconnecting said motor and said center shaft for rotating said shaft in a first direction, means interconnecting said first shaft and said planetary shaft for rotating said planetary shaft about its own axis in the opposite direction from the rotation of said center shaft and for simultaneously moving said planetary shaft planet-wise about said center shaft, said mixing head including a transverse lower wall, lubricating means disposed above said wall, sealing means carried by said wall for forming a seal between said wall and said shafts, means for drawing a vacuum above said transverse lower wall, and a dry well depending from said mixing head and including a transverse bottom wall carrying second sealing means in engagement with said shafts, means disposed below said transverse seal for drawing a vacuum upon said bowl.

4. A vertical mixer comprising a vacuum shroud having a lower shoulder adapted for airtight engagement with the rim of a bowl, a rotatable mixing head disposed within said vacuum shroud, a center shaft depending from said mixing head, a planetary shaft depending from said mixing head, an electric motor mounted upon said mixer, means interconnecting said motor and said center shaft for rotating said shaft in a first direction, means interconnecting said first shaft and said planetary shaft for rotating said planetary shaft about its own axis in the oppsite direction from the rotation of said center shaft and for simultaneously moving said planetary shaft planet-wise about said center shaft, said mixing head including a transverse lower wall, lubricating means disposed above said wall, sealing means carried by said wall for forming a seal between said wall and said shafts, and a dry well depending from said mixing head and including a transverse bottom wall carrying second sealing means in engagement with said shafts, first means for drawing a vacuum upon the interior of said bowl, sealing means extending inwardly from said shroud to form a transverse seal between said shroud and said mixing head, and second means for drawing a vacuum above said sealing means, whereby the pressure between said bowl and head is equalized.

5. A vertical mixer comprising a vacuum shroud having a lower shoulder adapted for airtight engagement with the rim of a bowl, a rotatable mixing head disposed within said vacuum shroud above said shoulder, a first shaft depending from said mixing head, a planetary shaft depending from said mixing head, an electric motor mounted upon said mixer, means interconnecting said motor and said first shaft for rotating said shaft in a first direction, means interconnecting said motor and said planetary shaft for rotating said planetary shaft about its own axis in the opposite direction from the rotation of said first shaft and for simultaneously moving said planetary shaft planet-wise, first means for drawing a vacuum upon the interior of said bowl, sealing means extending inwardly from said shroud to form a transverse seal between said shroud and said mixing head, and second means for drawing a vacuum above said sealing means, whereby the pressure between said bowl and head is equalized.

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