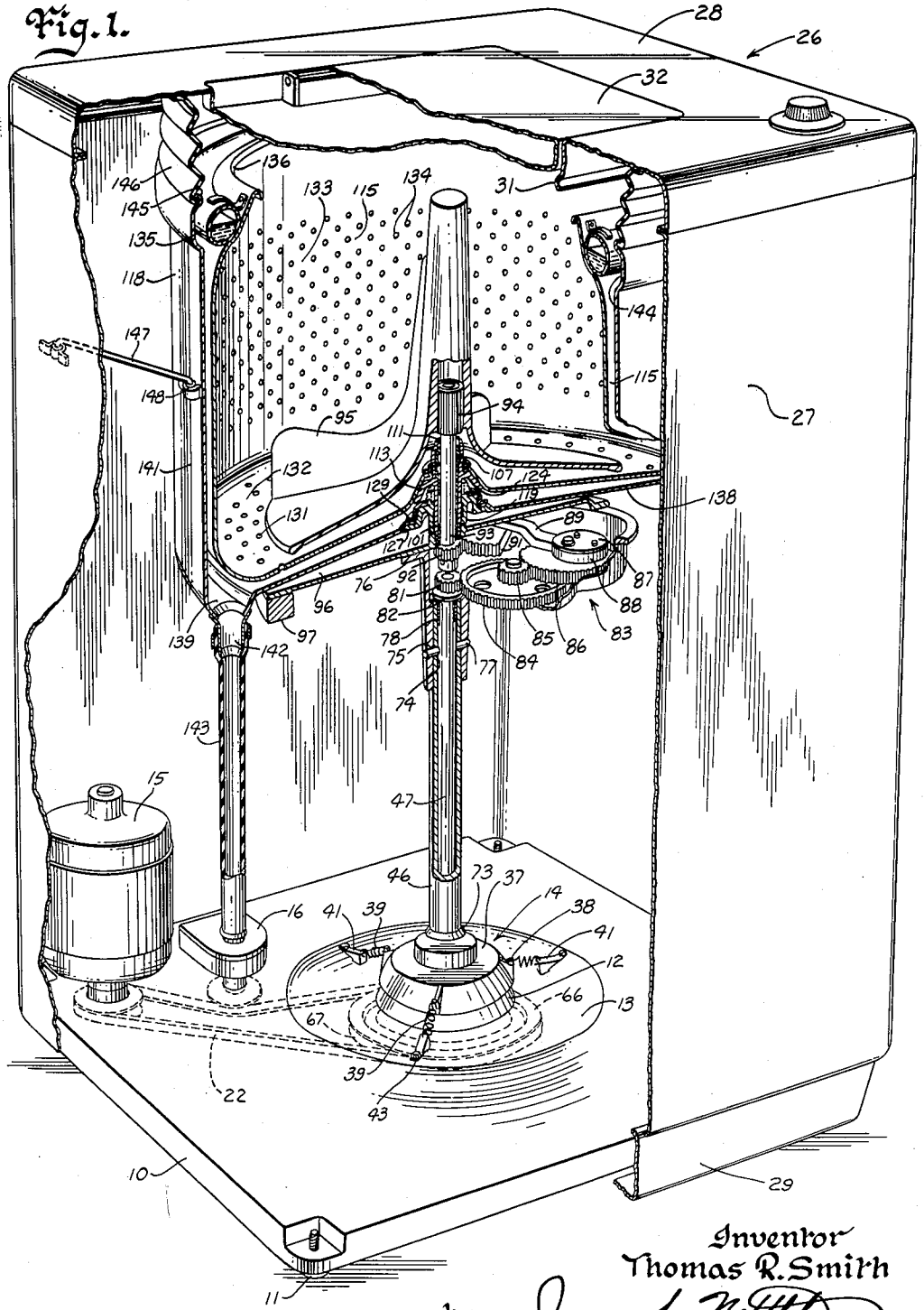
March 28, 1961 T. R. SMITH 2,976,998

DAMPING SYSTEM FOR A WASHING MACHINE

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Fig. 1.



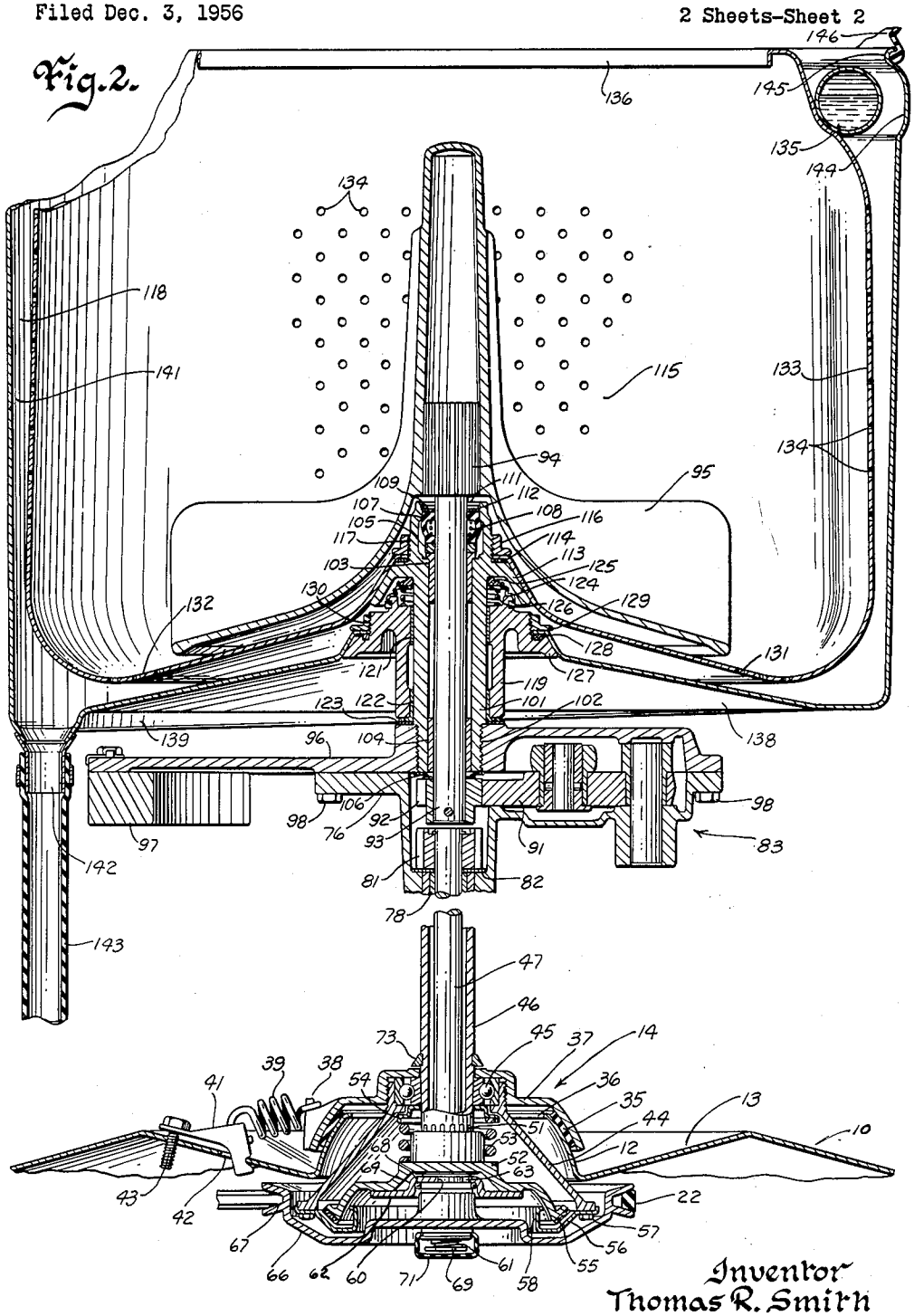
Inventor
Thomas R. Smith
by James L. Nettleton
Attorney

March 28, 1961 T. R. SMITH 2,976,998

DAMPING SYSTEM FOR A WASHING MACHINE

Filed Dec. 3, 1956 2 Sheets-Sheet 2

Fig. 2.



Inventor
Thomas R. Smith
by James L. Rottlet
Attorney

United States Patent Office 2,976,998 Patented Mar. 28, 1961

2,976,998

DAMPING SYSTEM FOR A WASHING MACHINE

Thomas R. Smith, Newton, Iowa, assignor to The Maytag Company, Newton, Iowa, a corporation of Delaware

Filed Dec. 3, 1956, Ser. No. 625,875

13 Claims. (Cl. 210—78)

This invention relates generally to an improved tub assembly mounting system for washing machines. While not necessarily limited to the vertical axis type machines, this invention is particularly adaptable for the inverted pendulum type machine such as that disclosed in my copending application, Serial No. 505,269, filed May 2, 1955, now Patent No. 2,930,215 and assigned to the assignee of the instant invention and of which this application forms a continuation-in-part.

It is a common practice in the laundry art to centrifugally extract fluids from saturated fabrics immediately following the conclusion of the agitation period during which the actual cleansing of those fabrics takes place. Depending upon the type mounting system used and the clothes load within the revoluble tumbler used for such extraction purposes, it is not uncommon to spin the clothes drum at speeds ranging generally from 200 r.p.m. to well over 600 r.p.m.

In rotating a drum or revoluble body at such speeds with unbalanced loads, which invariably exist with all clothes loads, disturbing forces of rather large magnitude, dependent again partially upon the particular machine construction, are created and transmitted to the supporting framework of the machine.

If the support standard or base member is not in some way partially isolated from those disturbing forces, these disturbing forces are directly transmitted to the supporting standard which will be accelerated from its normal static position at a rate inversely proportional to its mass and directly proportional to the forces acting upon it. This results in the machine's either being lifted from the floor or slid across the floor under the influence of these disturbing forces. To prevent this movement from taking place, some machines are rigidly connected to the floor which ultimately receives these forces under those circumstances.

Because a rigidly mounted machine is inconvenient for the user of a domestic type laundry machine, it is normally desirable to partially isolate these disturbing forces from a supporting standard to reduce the effects of the disturbing forces on the floor and supporting standard.

To appreciate the value of a resiliently mounted support system, it should be realized that while a harmonic disturbing force set up by a rigidly attached body is transmitted directly from that body to its supporting foundation, a disturbing force acting on a body completely free in space is restricted only by the inertia of that particular body which results in that body being accelerated through a harmonic oscillatory motion. By using a flexible mounting for the body from which these disturbing forces emanate, this completely free condition is approximated and approached.

Through the use of such a flexible mounting for a vibratory body, the disturbing forces emanating from that body are accommodated by the flexible mounting itself and only a portion of these forces necessary to overcome the resistance of the mounting to this motion are

therefore transmitted to the supporting structure. The magnitude of the portion of the forces transmitted to the supporting frame is a function of the ratio between the disturbing frequency of the vibrating body and the natural frequency of the mounting system supporting that body. This ratio may be termed the frequency ratio for this specification. Mathematically, this relationship is expressed by a mathematical formula known as the transmissibility formula:

$$\text{Transmissibility} = \frac{1}{\left(\frac{F}{f_n}\right)^2 - 1}$$

Where

F=disturbing frequency

f_n=natural frequency of mounted assembly and the result is the portion of the vibratory or disturbing force transmitted to the base as compared to the portion transmitted had a rigid connection been made between the vibratory body and its support in place of the resilient mounting system.

In substituting in this formula, it can be seen that as the ratio of the disturbing frequency to the natural frequency of the system approaches unity a magnification of the disturbing forces occurs until, at unity, a resonant condition is reached at which time the disturbing forces transmitted to the support become infinite if no damping is used in that system.

As this ratio of the disturbing frequency to the natural frequency exceeds unity, transmissibility diminishes from infinity until it is equal to unity when the ratio is equal to $\sqrt{2}$. The transmissibility at this frequency ratio is therefore equivalent to that which would result through the use of a rigidly mounted machine. As this ratio is increased beyond $\sqrt{2}$, transmissibility continues to diminish and approaches zero.

This transmissibility formula therefore indicates that a resiliently mounted system may be desirable when the frequency ratio of the disturbing frequency to the natural frequency of the mounting system is equal to or exceeds $\sqrt{2}$ and as this value becomes greater, it becomes more efficient than the rigidly supported vibratory member.

However, with an undamped system, a ratio of less than $\sqrt{2}$, especially a frequency ratio of unity, causes a magnification of the vibratory forces transmitted to the base support to occur. In other words, it would be preferable to restrain or damp free movement of the vibratory body until the ratio of its vibration frequency to the natural frequency of the resilient system equalled or exceeded the value of $\sqrt{2}$.

It is toward such a system and method of operation that this invention is directed. By utilizing the weight of the washing fluid within the casing to damp the cyclical vibration created by the rotation of a revoluble basket or mass within that casing, the resilient mounting system can be highly damped at those lower rotational speeds producing frequency ratios of less than $\sqrt{2}$ while at the higher speeds which produce frequency ratios greater than $\sqrt{2}$ the damping of the system may be materially reduced to reduce the transmissibility value. With this method, a rotating member within that casing may be more easily brought through its critical speed, that speed at which the transmissibility is infinite for an undamped rotating member and at which speed resonance of the resilient mounting system occurs.

It is therefore an object of this invention to achieve a variably damped system in which a greater degree of vibration damping of the vibratory motion is produced when a revoluble clothes basket is accelerated through

its lower range of frequency ratios as compared with the lesser degree of damping produced at its higher frequency ratios.

It is also an object of this invention to utilize the weight of the washing fluid within the tub itself not only to increase the damping forces resisting nutational movement of the tub assembly but also to increase the mass and inertia resisting these vibratory forces to thereby effectively reduce the amplitude of deviation of the basket from its normal balanced position.

It is also an object of this invention to retain washing fluids within the tub assembly so long as the clothes basket speeds are such as to produce frequency ratios of less than unity so that the washing fluid will not only increase the frictional damping at lower basket speeds but also will tend to act as a fluid balancing ring and maintain the tub assembly in a balanced condition as the basket is brought up to full speed.

It is also an object of this invention to provide a washing machine in which the rotational speed of the extractor basket and the fluid discharge rate of the pump emptying the imperforate casing encompassing that basket are so coordinated in operation that the casing is emptied of fluids prior to the basket's reaching full speed but after it has substantially exceeded the region of resonance of the system.

Other objects, advantages and features of this invention will be more apparent when reference is made to the following specification and drawings in which:

Figure 1 is a perspective view of an automatic washing machine embodying my invention and showing the relationship of my tub assembly with respect to cooperating assemblies supporting and powering the tub assembly, and

Figure 2 is a vertical elevation showing the detailed parts of the tub assembly of the machine shown in Figure 1 and the associated drive assembly for that machine.

In these drawings, there is shown a base member 10 mounted on adjustable feet 11 and provided with a supporting dome 12 rising out of a centrally located depression 13 in base 10, Dome 12 serves as a mounting for a drive assembly 14 such as that of the John D. Goodlaxson application, Serial No. 505,231, filed May 2, 1955, now Patent No. 2,948,372, and assigned to the same assignee as that of the instant application.

Base member 10 also supports the upended reversible motor 15 and water pump 16, which like drive assembly 14 is driven by motor 15 through belt 22 carried beneath base frame 10. In order to secure a constant driving speed for water pump 16 while simultaneously limiting the torque requirements imposed upon motor 15 by drive assembly 14 during the centrifugal extraction operations, it is preferable, when using the single belt drive shown in the accompanying drawings, to provide some form of torque limiting clutch device between the input pulley of drive assembly 14 and the driven member within the hub of that pulley in order to protect motor 15 from overloads.

If separate drive belts are used to power drive assembly 14 and water pump 16 as has been done in practice, then the slip belt torque limiting clutch construction disclosed and claimed in my Patent No. 2,653,483, issued September 29, 1953, may be used to drive assembly 14 while water pump 16 can be directly driven by motor 15 through a separate belt.

The cabinet 26 formed from wrap-around portion 27, removable top portion 28 and toe board 29 is attached to and encloses base 10 together with the drive and tub assemblies supported thereby. Cabinet 26 also acts to reinforce base 10 against the torsional stresses exerted on that base member during operation of the machine. Cabinet 26 is provided with an access opening defined by the depending flange 31 in cover portion 28. This access opening is covered by closure 32 during normal operation of the washing apparatus.

The specific details of the drive assembly 14 supporting and controlling the tub assembly and forming the subject matter for the aforesaid Goodlaxson application will now be briefly described.

In Figure 2, it can be seen that the truncated dome 12 is provided with friction pads 35 on its periphery adjacent the aperture 36 in its uppermost portion. An umbrella-like support member 37 rests on these friction pads 35 and is provided with three equally spaced ears 38 for the three centering springs 39. The opposite, ends of the centering springs 39 are each attached to an L-shaped bracket member 41 having a first pair of notched bifurcated legs fitted into a rectangular opening 42 in base frame 10 and a second leg fastened to base member 10 by means of an anchor screw 43 threaded into that base member. This not only centers and restrains umbrella member 37 against rotation but also provides a means for partially regulating the minimum degree of damping of the gyratory movements of umbrella member 37 on pads 35. While the accompanying drawings indicate the use of only three centering springs 39, additional springs may be used.

Threaded into umbrella member 37 is the stator support member 44 which cooperates with member 37 by gripping the outer race of the thrust bearing 45 provided with a tapered inner race. Mating with and seated in this tapered inner race of bearing 45 is the spin tube or shaft 46 which journals a power shaft 47 extending past the lower end of tube 46. With this construction, all weight placed on the vertical tube 46 creates a frictional force resisting relative movement between support member 37 and base frame 10 and therefore may be used to an advantage to provide an ample frictional force between member 37 and pads 35 for damping nutational movements of the shafts 46 and 47.

The lower end of tube 46 is provided with splines 51 which mate with internal splines of rotor member 52 so as to allow the latter member to move relative to tube 46 in an axial direction only. Rotor 52 is urged downwardly by means of a large coil spring 53 abutting rotor member 52 and a spring retainer member 54 which in turn presses upwardly against the inner race of bearing 45.

Spring 53 moves rotor member 52 downwardly until brake lining 55, cemented to the beveled edge of rotor member 52, engages the brake stator 56 which is fastened to stator support member 44 by means of the cap screws 57 threaded into the latter member. Annular flange 58 extending upwardly from the brake stator 56 provides a reservoir for a small quantity of lubricating fluid in case a drive brake lining is not desired.

That lower portion of power shaft 47 extending beyond the lower end of tube 46 is provided with a flat 60 and a helix 61 adjacent each other. A clutch member 62 having a D-shaped opening 63 in its raised central portion 64 slides over the helix 61 and seats on flat 60 so that clutch member 62 may move axially of shaft 47 but is restrained against rotation relative to that latter shaft.

The contoured pulley 66 covering the bottom portion of the drive assembly 14 is threaded onto helix 61 permitting pulley 66 to spiral upwardly or downwardly on helix 61 as determined by the direction of rotational movements imparted to pulley 66 by the reversible motor 15 through belt 22.

When using a single belt to drive pulley 66 and water pump 16, it is preferable to prevent the imposition of any overloads on motor 15 during the spin period by incorporating some from of torque limiting clutch such as that described and claimed in my Patent No. 2,604,764, which issued July 29, 1952 to the assignee of the instant invention between that portion of pulley 66 engaging helix 61 and the driving rim of that pulley. This torque limiting clutch construction which is hidden from view by the hub of pulley 66 in Figure 2 permits full speed rotation of pump 16 while simultaneously limiting the torque requirements imposed upon motor 15 by assembly

14 during the initiation of the centrifugal extraction operations.

It should be apparent that drive assembly 14 and water pump 16 may be driven by motor 15 through separate belts to perform the same functions. If separate belts are used, then the slip belt torque limiting clutch construction disclosed and claimed in my Patent No. 2,653,-483, issued September 29, 1953, may be used to drive assembly 14 through a drive pulley incorporating no such torque limiting device and still allow water pump 16 to be driven at a constant speed through a separate belt.

It should be noted that while tube 46 is supported by dome 12, concentric shafts 46 and 47 actually nutate on a point determined by the radii of curvature of this dome. This is substantially the same point as the intersection of the radii of curvature of that surface of member 37 engaging pads 35. In the modification of this drive assembly shown in the accompanying drawings, this point is also the intersection of the shaft's axis of rotation with the horizontal plane bisecting groove 67 of pulley 66.

The central portion 64 of clutch member 62 serves as the outer race for balls 68 so as to permit relative rotary movement to take place between clutch member 62 and upper end of pulley 66 which provides the inner race for those balls.

Pulley 66 is prevented from turning itself off the bottom end of shaft 47 by means of a left hand cap screw 69 threaded into the lower end of shaft 47. With this construction, a spiral movement of pulley 66 downwardly against cap screw 69 tends to tighten the latter into shaft 47. Resilient seal 71 provides a means for keeping foreign matter out of helix 61 and the space between the abutting surfaces of pulley 66 and cap screw 69.

Now with reference to the tub assembly disclosed in this illustrative machine, it can be seen that tube 46 extends upwardly from tub drive assembly 14 and past the deflector seal 73 keeping foreign liquids and particles out of drive assembly 14. The upper end of tube 46 is provided with a pair of diametrically opposed holes 74 which mate with holes 75 formed in the lower extension of the lower power housing cover 76. By inserting pins 77 into these mating holes 74 and 75, the lower power housing cover 76 becomes a unitary extension of tube 46.

The upper end of tube 46 is provided with a bushing 78 which journals the power shaft 47 for rotation within tube 46. Securely fastened to the upper end of shaft 47 is a drive pinion 81 which rests upon a thrust washer 82 within the lower power housing cover 76 to prevent shaft 47 from moving downwardly within tube 46. It should be apparent that with this construction shaft 46 and thrust bearing 45 support shaft 47 in addition to all weight placed on lower gear case cover 76.

In order to obtain an oscillatory movement from the rotary motion imparted to power shaft 47, a motion converting unit 83 is provided. In unit 83, the input pinion 81 rotates spur gear 84 and its affixed pinion 85 which in turn rotates gear 86. Gear 86 is affixed to an eccentric 87 which rotates within strap 88 to rock the segmental gear 91 through pitman 89. The rocking segmental gear 91 oscillates the driven pinion 92 affixed to the agitator drive shaft 93 which in turn is fastened by means of the splines 94 to the conventional agitator 95.

To enclose and counterbalance motion converting unit 83, the upper power housing cover 96 carrying counterweight 97 is secured to the lower casing cover 76 by means of cap screws 98. In addition to enclosing and counterbalancing unit 83, top cover 96 provides a support for the stub shaft or vertical mounting stem 101 threaded into top cover 96 by means of threads 102. It should be noted that other types of motion converting units may be used in the power housing formed by covers 76 and 96 in order to drive agitator shaft 93.

Stub 101 is provided with upper and lower bushings 103 and 104, respectively, journalling the agitator shaft 93 and maintaining that latter shaft in its vertical position. Pressed onto shaft 93 near its upper end is a thrust collar 105 which is resiliently urged against the upper bushing 103 by means of the flexible thrust washer 106 between the driven pinion 92 and the lower end of stub shaft 101.

Urged against the top side of collar 105 is the shaft seal 107 which encloses coil spring 108 and presses upwardly against the washer 109 maintained in its position at mouth 111 of stem 101 by means of an expansible C-ring 112 engaging an annular mating groove within mouth 111.

Mounting stem 101 is provided with a basket mounting flange 113 which serves as a seat for gasket 114 and the perforate tub or basket 115 which is forced against gasket 114 by means of the large nut 116 mating with threads 117 on the mounting stem 101. This connection between basket 115 and the mounting stem 101 prevents any relative rotation between these members and provides a unitary connection between tube 46 and basket 115.

Basket 115 nests within a non-rotating outer tub 118 which is secured to a tub journal bearing or tub carrier 119 by means of connections similar to those used in attaching basket 115 to stem 101. Tub carrier 119 is provided with an upper bushing 121 and a lower bushing 122 both of which journal mounting stem 101 and the latter of which rests upon a thrust washer 123 carried on the top side of the upper power housing cover 96 so as to permit relative rotation between the mounting stem 101 and the tub carrier 119. The upper end of carrier 119 is provided with a resilient bellows type seal 124 formed integrally with an annular carbon nose seal ring 125 urged against the lower side of annular flange 113 by means of a coil spring 126.

Imperforate tub 118, spaced from basket 115, has its central portion mating with a mounting flange 127 and is pressed against a resilient beaded gasket 128 by means of a large nut 129 mounted on the threads 130 of tub carrier member 119 and having an inner diameter larger than the largest diametrical extent of flange 113. This produces a unitary waterproof connection between tub 118 and the tub carrier 119.

While tub 118 and basket 115 may be connected to their respective supporting flanges by machine screws or suitable methods, it should be apparent from this description that the disclosed construction lends itself to easy repair and assembly. Once agitator 95 and cabinet top 28 have been removed, one need only to unscrew nut 116 to remove basket 115 from cabinet 26. After basket 115 has been removed, tub 118 can also be removed in a similar manner by loosening its drain hose connection, unscrewing nut 129 and taking tub 118 from its supporting flange 127.

Basket 115 slopes downwardly from annular flange 113 beneath agitator 95 and is provided with three rows of holes 131 in the lowermost portion of its bottom wall 132 before rising into the nearly cylindrical side wall 133 provided with holes 134 and supporting a hollow balancing ring 135 partially filled with fluid near the rolled edge 136 defining an access opening into basket 115.

Tub 118 is provided with an imperforate bottom wall 138 which slopes downwardly from its mounting flange 127 in a nearly parallel relationship to bottom wall 132 of basket 115 before merging into a C-shaped gutter 139 at its junction with the cylindrical side wall 141. As is apparent from Figure 2 gutter 139 is of varying depths with its shallowest portion beginning diametrically opposite its deepest portion which is immediately over the drain 142 leading to water pump 16 through drain hose 143.

Cylindrical wall 141 is imperforate and is provided with an annular recess 144 adjacent balancing ring 135 to create clearance between these parts and add to the strength of the outer tub 118. The lip 145 formed at the upper edge of wall 141 serves as an anchor for a

large beaded bellows seal 146 which presses upwardly against and slides on the lower side of cabinet top 28 to seal and prevent the escape of steam from within the tub assembly without in any way impairing the tub assembly from any freedom of movement from the vertical axis. Since this vapor seal forms no part of the instant invention, other forms of tub crowns for tub 118 may be used for the tub assembly utilizing my resilient supporting system.

Though the drag forces caused by the rotation of mounting stem 101 may tend to cause the rotation of tub carrier 119 and its attached tub 118, drain hose 143 connected between tub 118 and water pump 16 prevents outer tub 118 from following any rotational movements imparted to mounting stem 101. If it is desired to relieve these torsional forces from hose 143, other tub restraining devices such as link 147 connected between cabinet portion 27 and tub 118 and mounted in rubber grommets 148 may be used to anchor and to prevent rotation of tub 118. It is preferable that the use of such tub restraining devices do not interfere with the nutational movements of tub 118.

In operation over typical agitation and spin periods, the fabrics to be cleaned are inserted into basket 115 through the access openings defined by depending flange 31 and rolled edge 136. A suitable detergent is added to the water placed within tub 118 by a water supply system not forming a part of this invention. Though a valve may be used in the drain hose 143 to prevent the washing fluids from draining from tub 118, the water may be retained within tub 118 in this illustrative embodiment by merely maintaining the external drain hose (not shown) attached to the outlet of pump 16 at a higher elevation than the elevation of the water contained within tub 118.

During the tub filling period when the liquid rising within tub 118 has covered holes 131 in basket 115, air is trapped between bottom walls 132 and 138 due to the presence of seal 124 and the air tight connections between basket 115 and tub 118 and their respective flanges 113 and 127. This prevents fluids from contacting seal 124 or nut 129. Likewise, when the liquid level rises above the lower edge of agitator 95, air is trapped beneath agitator 95 and prevents liquids from contacting either seal 107 or nut 116.

When tub 118 has been filled with a sufficient quantity of washing fluid, the reversible motor 15 is energized through a control system (not shown) to rotate the pulley 66 in a clockwise direction as viewed in Figure 1. Rotation of pulley 66 in this direction causes pulley 66 to spiral downwardly on helix 61 until it abuts the head of cap screw 69. After this engagement between these parts has been made, further rotation of pulley 66 rotates inner shaft 47 to the exclusion of tube 46 which continues to be restrained against rotation by the braking action of rotor 52 which is pressed against stator 56 by means of the coil spring 53. This rotation of shaft 47 and its attached pinion 81 drives through the motion converting unit 83 so as to produce an oscillatory movement for agitator drive shaft 93 and its attached agitator 95 during the agitation period.

The oscillating action of agitator 95 forces the cleaning fluid through the fabrics within basket 115 and separates impurities held by them. The heavier and larger particles such as sand and sediment fall to the bottom of basket 115 where they pass through holes 131 in the lowermost portion of bottom wall 132. This agitation of fluids within tub 118 also causes these heavier particles to work their way down the sloping wall 138 and into the gutter 139 around the periphery of that bottom wall. Once in this gutter 139, these particles continue to seek a lower elevation in the agitated fluid and find their way into the deepest part of gutter 139 and eventually into the drain outlet 142 in the lowermost portion of tub 118.

Upon completion of the agitation cycle and the initiation of the spin or liquid extraction period, motor 15 is reversed causing the water pump 16 and drive assembly pulley 66 to reverse their directions also. When driven in this direction, water pump 16 is permitted to pump the washing fluid together with the accumulation of sand and sediment from tub 118 through its drain connections.

This reversal of driving power causes pulley 66 to spiral upwardly on helix 61 against balls 68 and move clutch plate 62 upwardly against the urging of coil spring 53. Upward movement of clutch member 62 causes this latter member to engage and lift rotor member 52 away from the brake stator 56 freeing rotor 52 and drive tube 46 for rotation. However, relative rotation between pulley 66 and clutch member 62 on balls 68 continues until clutch member 62 either abuts the lower end of spin tube 46 or is prevented from further upward travel once the forces acting on pulley 66 by spring 53 are in equilibrium with those produced by the power imparted to pulley 66 through belt 22. This causes member 62 to cease its upward travel with the result that balls 68 become wedged between clutch member 62 and rotor 52 and prevent further upward travel of pulley 66 on helix 61. Further rotation of pulley 66 therefore causes tube 46 to rotate in a counterclockwise direction as viewed from the bottom of Figure 1 through a power path provided through pulley 66, shaft 47, flat 60, clutch member 62 and rotor 52. This causes shafts 46 and 47 to rotate in unison with their driven assemblies.

It should be noted at this point that when pump 16 and drive assembly 14 are stopped and immediately reversed as illustrated in this embodiment the water retained by tub 118 during the agitation period is still present within that tub.

The presence of this washing fluid is beneficial in the operation of this machine in several interrelated ways. First, the weight of all fluid retained within tub 118 is carried by the tub carrier 119 which is supported on the upper side of the motion converting unit 83 which is in turn ultimately supported on the spin tube 46. Since the spin tube 46 is journalled in the thrust bearing 45, the additional weight of the fluids within tub 118 increases the force exerted by member 37 on friction pads 35 thereby increasing the frictional force resisting relative movement of these two parts. In practice, this additional fluid weight creates a contact force between parts 35 and 36 which nearly equals the contact force between these parts attributable to the tension springs 39. In other words, with a given frictional coefficient, the damping force resisting movement of tub 118 relative to base frame 10 is nearly doubled with a full tub of water over that of an empty tub assembly.

Second, the presence of water within tub 118 increases the mass and inertia of the inverted pendulum tub assembly system. This increased mass and inertia means, of course, that it would take a greater unbalanced force to move the tub assembly a given distance from its vertical position thus allowing greater unbalanced clothes loads to be carried in the tub than would be carried under those conditions in which no water was present within tub 118.

Third, the presence of water in tub 118 at times when basket 115 is rotated at speeds exceeding its critical speed causes the water within tub 118 to act as a fluid balancing ring similar to ring 135 when the rotating basket rotates about its center of gravity rather than about its geometric center. This causes the fluid within tub 118 to aid in balancing this system above the critical speed so long as there is water present within tub 118. Its practical effect is to aid in bringing basket 115 up to full speed which exceeds the critical speed. Blow the critical speed the system is so heavily damped and the basket speed of rotation so relatively low that the mass of water does not materially aggravate any existing unbalanced load condition.

Since water pump 16 is reversed when motor 15 and

pulley **66** are reversed, water immediately is pumped from tub **118** through hose **143** and out of the exit drain hose (not shown) connected to pump **16** when basket **115** starts to rotate.

At the start of this spin period the inertia of the basket filled with clothes immersed in the fluid retained within tub **118** is naturally quite high. Since the torque necessary to accelerate the basket **115** rapidly up to speed is much greater than the torque capable of being supplied by the fractional horsepower motor **15**, the torque limiting clutch incorporated within the hub of pulley **66** in this illustrative disclosure limits the loading on motor **15**. This limitation of torque available to spin tube **46** causes that tube and its affixed basket **115** to accelerate slowly against the hydraulic drag of fluids surrounding basket **115**.

As the water within tub **118** is pumped from that tub by water pump **16**, the inertia and hydraulic drag become progressively less allowing the angular acceleration of basket **115** to increase. By the time that basket **115** has been accelerated to 90 or 100 r.p.m., the cyclical rotational speed equal to the resonant frequency of the resiliently mounted inverted pendulum system under empty tub conditions, only one or two gallons of water out of the total of 15 or 16 gallons have been pumped from the tub **118**. Should this same rate of fluid flow be utilized in a partial fill machine having full, medium and low liquid level settings of 16, 13 and 10 gallons respectively, for example, it can be seen that even with the low setting, 50% of the fluid capacity of tub **118** would be retained within that tub at the time basket **115** reached this range of speeds. This, of course, does not take into consideration the fact that basket **115** will accelerate faster with less fluid in tub **118** at a low liquid level setting consequently will take less time in getting to this range of speeds.

Under empty tub conditions which would exist if all water were drained from tub **118** before rotation of basket **115** were to be initiated, it has been determined by experimentation that for a particular machine as basket **115** approaches 90 to 100 r.p.m., the cyclical rotational speed equivalent to the resonant frequency of the resiliently mounted inverted pendulum tub assembly, a magnification of the disturbing forces caused by the rotation of an unbalanced clothes load and transmitted to base frame **10** will occur. This is in accordance with the transmissibility formula originally set forth in the explanation of the objects of this invention.

This magnification of the disturbing forces transmitted to the base frame **10** through their reinforcement by the resilient mounting system in this region of magnification when the frequency ratio is approximately unity, tends to approach infinity unless adequate damping is provided to reduce this resonant build-up.

By relying upon the weight of the washing fluid within tub **118** to temporarily increase the frictional damping resisting movement of member **37** relative to friction pads **35**, the transmissibility value of the previously mentioned transmissibility formula under these substantially full tub conditions is reduced to such a degree that it approaches the minimum value of unity (for frequency ratios less than $\sqrt{2}$) rather than the theoretical high limit value of infinity for this lower range of speeds.

In addition, the increased weight of the fluids within the tub itself increases the mass and inertia of the inverted pendulum tub assembly so that greater unbalanced forces are necessary to move the tub assembly a given distance toward the walls of cabinet **26**. This means that clothes loads creating greater unbalanced conditions can be accelerated through critical speed, that speed at which the basket's cyclical rotational speed is equivalent to the resonance of the flexibly mounted tub assembly and at which speed the amplitude of deviation from the vertical is ordinarily at a maximum. This amplitude of deviation from the vertical may be affected by varying the degree of damping or the inertia of the mounting system while the basket is rotating through its range of speeds.

As basket **115** accelerates and revolves at a higher angular velocity, it passes through that speed which exceeds the momentary resonant frequency of the tub mounting system by a ratio factor of $\sqrt{2}$. This is termed a momentary resonant frequency since the resonant frequency of this mounting system is partially dependent upon the amount of water within the imperforate tub which is steadily emptied by pump **16**. This speed must necessarily be less than 141 r.p.m., assuming an empty tub resonant frequency of 100 cycles per minute for illustrative purposes, since the resonant frequency is naturally decreased with an increased mass within tub **118**.

Beyond this speed, as indicated in the objects of this invention, it is advantageous to decrease damping to produce a more efficiently isolated mounting system so that the transmissibility values may decrease to values well below unity.

It should be noted at this point that even assuming a tub assembly resonant frequency of 80 cycles per minute under full tub conditions as compared with a tub assembly resonant frequency of 100 cycles per minute under empty tub conditions there will be only a small difference in instantaneous resonant frequencies at the time that the basket speed equals the tub assembly resonant frequency as compared with the time when the basket speed exceeds the slightly greater resonant frequency when the frequency ratio is equal to a value of $\sqrt{2}$. This small difference is due to the much greater acceleration of basket **115** as compared with the rate of change in the tub assembly's resonant frequency. Beyond this frequency ratio of $\sqrt{2}$ (when the transmissibility falls below unity) the slight variations in the resonant frequency of the tub assembly have little effect due to the much higher rate of speed of basket **115**. A prime effect of this variance in these resonant frequencies is to broaden the region of speeds in which magnification of the unbalanced forces occur. This broadening of the region of magnification is more than offset, however, by the advantages of the increased damping provided by this invention.

For explanatory purposes in this specification and the appended claims, the frequency identified by the term resonant frequency is meant to specify that frequency at which the variably filled tub assembly would resonate at the instant that the basket or rotating mass within tub **118** is revolving at a designated speed.

For example, when compared to the critical speed of basket **115**, the resonant frequency specified will be that frequency having a period equally the rotational period of basket **115**. In other words, the frequency ratio under these conditions would be unity.

When compared to a higher speed exceeding the resonant frequency by a ratio factor equal to $\sqrt{2}$, the latter resonant frequency will be a frequency which is higher than the resonant frequency mentioned in the previous paragraph and one whose instantaneous cyclical speed would be exceeded by that of the rotating basket by a ratio factor of $\sqrt{2}$. As previously stated, this variance in resonant frequencies of the tub assembly is caused by the variable quantities and positioning of the fluid carried by the tub assembly.

Since it has been pointed out that these resonant frequencies may in practice vary only to a slight degree, these explanatory paragraphs are meant only to lend definition to this specification without unduly limiting the spirit of this invention.

By coordinating the pumping of the washing fluid from tub **118** with the angular velocity of basket **115** it is possible to retain a sufficient quantity of fluids within tub **118** until after basket **115** has been rotated at speeds which exceed the $\sqrt{2}$ frequency ratio, or 141 r.p.m. as would be the case with the last set of illustrative figures. In this embodiment, even though pump **16** is directly driven,

this coordination is achieved by pump design, pump pulley speed, etc., but it may be also achieved by a different type control system regulating the time of operation of pump 16 relative to that of pulley 66.

It should be noted here that rotation of basket 115 under full tub conditions does not cause an overflow of washing fluid past seal member 146 since the high torque necessary for high speed rotation of basket 115 to produce such a resulting overflow is prevented by the torque limiting clutch incorporated in this illustrative embodiment. Since this feature is independent of the particular type fluid retaining member attached to lip 145, it would also be applicable to that type tub construction utilizing a tub crown attached to lip 145 and provided with an access opening concentric to rolled edge 136. By the time that basket 115 is rotating at a higher range of speeds enough water has been drained from tub 118 to prevent such an overflow at those higher speeds. This, of course, is an advantage of limiting the amount of torque supplied to basket 115.

In practice, basket 115 has been accelerated through the speeds just exceeding the frequency ratio of $\sqrt{2}$ as the hydraulic coupling existing between basket 115 and the water within tub 118 is substantially broken allowing basket 115 to quickly rise to its full speed of about 618 r.p.m. just after tub 118 has been completely emptied.

This completely eliminates the frictional damping attributable to the water within tub 118 and thereby cuts the damping to a value of approximately half of its original value. The result is that the damping utilized at those lower rotational speeds of basket 115 to damp vibrations occurring in the range of the critical speed is materially reduced to provide a more efficient vibration isolation system at speeds well above the critical speed. In viewing the results in a different way, it can be said that with a given amount of fixed damping at the end of the spin cycle, greater unbalanced load conditions can be tolerated at the beginning of the spin cycle with this system than would be possible if the tub were completely emptied of fluid prior to the initiation of the spin cycle.

At the end of the spin dry operation motor 15 is stopped causing drive pulley 66 to lose angular momentum. The inertia of the tub assembly driven by shafts 46 and 47 causes the shafts to continue their rotation so that relative rotation between pulley 66 and shaft 47 results. This relative rotation between pulley 66 and helix 61 causes pulley 66 to spiral downwardly on helix 61. The coil spring 51, which constantly forces downwardly on rotor 52, causes rotor 52, clutch member 62 and balls 63 to follow the downward travel of these parts. These parts progress downwardly in unison until rotor 52 engages brake stator 56 to quickly stop the rotation of the spin tube 46 and basket 115. Inner shaft 47 when released from its driving connection with shaft 46 also comes to a quick stop due to the drag forces acting on pulley 66 and motor 15. Though these periods may be repeated and rinse periods added, this terminates the spin period of my illustrated operational cycle.

This method of operation is not dependent upon the specific type of construction illustrated in the accompanying figures. Its application extends also to that type tub construction disclosed and claimed in the copending Charles W. Burkland application Serial No. 518,163, filed June 27, 1955, now Patent No. 2,942,445, and assigned to the assignee of the instant invention. In the disclosed device of that application the weight of the imperforate outer tub is supported directly on a damper member, similar to that member 37 disclosed in the instant application, by means of a plurality of brace members rigidly interconnecting those members. It should be readily apparent that such a construction or similar constructions would, like that disclosed in Figures 1 and 2, also be capable of utilizing the weight of the washing fluid to damp deviation of the tub assembly at the beginning of the spin period while reducing the damping of the resiliently mounted tub support system at the end of the spin period by emptying that outer imperforate tub during that spin period.

It should also be apparent from this operational description that it is considered to be within the scope of this invention to attach the centering springs direclty to the tub 44 or to any brace members which might rigidly interconnect tub 118 with member 37 since that modified centering system would function similarly to that illustrated in Figures 1 and 2.

While only one embodiment of my invention has been shown in the accompanying drawings, it is understood that modifications of this embodiment may be made without departing the scope of my invention as set forth in the following claims.

I claim:

1. The method of centrifugally extracting fluids from fabrics which have been washed in the presence of a fluid, which comprises, initiating rotation of a perforate basket containing said fabrics immersed in said fluid to a rotational speed exceeding by a ratio factor of $\sqrt{2}$ the resonant frequency of a resilient mounting system supporting a casing containing said fluid, damping gyratory movement of said casing mounting system directly proportional to the combined weight of said basket and said fluid contained therein, and then completely emptying said casing of said fluid and removing the weight of said fluid from said mounting system and bringing said basket up to its highest extraction speed.

2. The method of centrifugally extracting fluids from fabrics which have been washed in the presence of a fluid, which comprises, rotating a perforate basket containing said fabrics immersed in said fluid to a first rotational speed exceeding by a ratio factor of $\sqrt{2}$ the resonant frequency of a resilient mounting system supporting a casing containing said fluid, damping gyratory movement of said casing directly proportional to the weight of said casing and fluid contents, emptying said casing of enough fluid to substantially eliminate hydraulic drag on said basket in said fluid at speeds exceeding said first rotational speed, and then completely emptying said casing of said fluid and removing the weight of said fluid from said mounting system and bringing said basket up to its highest extraction speed.

3. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide varying degrees of damping of said gyratory movements dependent upon the combined weight of said container and its fluid contents, comprising, rotating said container and said fabrics in said body of fluid from rest to speeds exceeding the critical speed of rotation of said container, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, discharging said fluid from said container during its acceleration to said speeds, and coordinating said fluid discharge with the rotational speed of said container so that substantially all of the fluid discharged from said container is discharged from said container and the weight of said discharged fluid removed therefrom after said container has surpassed its critical speed so that a minimum degree of damping of said container is produced at said speeds exceeding said critical speed.

4. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide varying degrees of damping of said gyratory movements dependent upon the combined weight of said container and its fluid contents, comprising, rotating said container and said fabrics in said body of fluid from rest

to speeds exceeding the critical speed of rotation of said container, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, discharging said fluid from said container during its acceleration to said speeds, and coordinating said fluid discharge with the rotational speed of said container so that subtsantially all of the fluid discharged from said container is discharged and the weight of said discharged fluid removed therefrom after said container has reached a predetermined speed exceeding its critical speed by a ratio value of $\sqrt{2}$ so that a minimum degree of damping of said continer is produced at speeds exceeding said critical speed.

5. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide varying degrees of damping of said gyratory movements dependent upon the combined weight of said container and its fluid contents, comprising, rotating said container and said fabrics in said body of fluid from rest to speeds exceeding the critical speed of rotation of said container, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, discharging said fluid from said container during its acceleration to said speeds, and coordinating said fluid discharge with the rotation speed of said container so that a major proportion of said fluid is discharged from said container and the weight of said discharged fluid removed therefrom only after said container has surpassed its critical speed.

6. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide varying degrees of damping of said gyratory movements dependent upon the combined weight of said container and its fluid contents, comprising, rotating said container and said fabrics immersed in said fluid from rest to speeds exceeding the critical speed of rotation of said container, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, discharging said fluid from said container during its acceleration to said speeds, and coordinating said fluid discharge with the rotational speed of said container so that a major proportion of said fluid is discharged from said container and the weight of said discharged fluid removed therefrom after said container has surpassed its critical speed by a ratio value of $\sqrt{2}$.

7. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide a varying degree of damping of said gyratory movements dependent upon the combined weight of said container and its fluid contents, comprising, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, accelerating said container and said fabrics immersed in said body of fluid from rest to a rotational speed which is less than the critical speed of rotation of said container, increasing the rotational speed of said container and fluid and gradually discharging said fluid from said container in a controlled discharge so that substantially all of said fluid remains within said container at the time said container reaches its critical speed, accelerating said container to higher speeds exceeding said critical speed, and then discharging the remaining quantiy of said fluid from said container and the weight of said discharged fluid removed therefrom during such latter acceleration so that a minimum degree of damping of said container is produced at such higher speeds in the absence of said fluid.

8. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide a varying degree of damping of said gyratory movements dependent upon the combined weight of said container and its fluid contents, comprising, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, accelerating said container and said fabrics immersed in said body of fluid from rest to a rotational speed which is less than the critical speed of rotation of said container, increasing the rotational speed of said container and gradually discharging said fluid from said container in a controlled discharge so that substantially all of said fluid remains within said container at the time said container reaches a predetermined speed exceeding its critical speed by a ratio of $\sqrt{2}$, accelerating said container to higher speeds exceeding said predetermined speed, and then discharging the remaining quantity of said fluid from said container during such latter acceleration so that a minimum degree of damping of said container and removing the weight of said discharged fluid therefrom is produced at such higher speeds in the absence of said fluid.

9. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported on a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide varying degrees of damping of said gyratory movements relative to said damping surface dependent upon the combined weight of said container and its fluid contents, comprising, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, rotating said container and said fabrics within said body of fluid below said critical speed of said container, gradually discharging said fluid from said container and removing the weight of said discharged fluid from said container during said rotation, increasing the rotational speed of said container during said fluid discharge and coordinating said fluid discharge with the rotational speed of said container so that a major proportion of said fluid remains within said container at the time said critical speed is reached, continuing said fluid discharge from said container above said critical speed, and then accelerating said container to its highest extraction speed in the absence of said fluid so that the degree of damping for said container is reduced to a minimum at said highest extraction speed.

10. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide varying degrees of damping of said gyratory movements are dependent upon the combined weight of said container and its fluid contents, comprising, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, rotating said container and said fabrics within said body of fluid below the critical speed of said container, gradually discharging said fluid from said container during said rotation, increasing the rotational speed of said container during said fluid discharge and coordinating said fluid discharge with the rotational speed of said container so that a major proportion of said fluid is discharged from said container and the weight of said discharged fluid removed therefrom after said container surpasses its critical speed, and accelerating said container to higher speeds in the absence of said fluid and the

weight thereof on said damping surface so that the degree of damping for said container is reduced to a minimum for said container at such higher speeds.

11. The method of centrifugally extracting fluid from fabrics immersed in a body of fluid within a revoluble container whose weight and fluid contents are supported by a damping surface resisting gyratory movements of said container relative to said damping surface so as to provide varying degrees of damping of said gyratory movements dependent upon the combined weight of said container and its fluid contents, comprising, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, initiating rotation of said container and said fabrics within said body of fluid below the critical speed of said container, restricting discharge of said fluid from said container during said rotation, increasing the rotational speed of said container during said fluid discharge and coordinating said fluid discharge with the rotational speed of said container so that a major proportion of said fluid is discharged from said container and the weight of said discharged fluid removed therefrom after said container surpasses its critical speed by a ratio value of $\sqrt{2}$, and accelerating said container to higher speeds in the absence of said fluid so that the degree of damping for said container is reduced to a minimum for said container at such higher speeds.

12. The method of centrifugally extracting fluid from fabrics retained within a revoluble container the weight of whose fluid contents is supported by a damping surface resisting gyratory movements of said container to provide varying degrees of amplitude damping of said gyratory movements dependent upon the weight of said fluid contents, comprising, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, rotating said container and said fabrics immersed in said fluid from rest to speeds exceeding the critical speed of rotation of said container, discharging said fluid contents from said container and removing the weight of said discharged fluid from said container during its acceleration to said speeds to permit centrifuging of fluid from said fabrics, and coordinating said fluid discharge with the rotational speed of said container so that the greatest proportion of fluid discharged from said container is discharged after said container has surpassed its critical speed so as to automatically provide the greatest degree of damping of said gyratory movements at speeds lower than said critical speed.

13. The method of centrifugally extracting fluid from fabrics retained within a revoluble container the weight of whose fluid contents is supported by a damping surface resisting gyratory movements of said container to provide varying degrees of amplitude damping of said gyratory movements dependent upon the weight of said fluid contents, comprising, damping said gyratory movements directly proportional to the combined weight of said container and its fluid contents, initiating rotation of said container and said fabrics and fluid contents from rest to speeds exceeding the critical speed of said container, discharging gradually said fluid contents from said container during its acceleration to said speeds to permit centrifuging of fluid from said fabrics and remove the weight of said fluid contents from said damping surface, and coordinating said fluid discharge with the rotational speed of said container so that the greatest proportion of fluid discharged from said container is discharged after said container has surpassed said critical speed by a speed ratio value of $\sqrt{2}$.

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