April 27, 1965 G. L. MALAN 3,180,624

VIBRATOR MOUNTING MEANS

Filed Feb. 11, 1963

FIG. 1

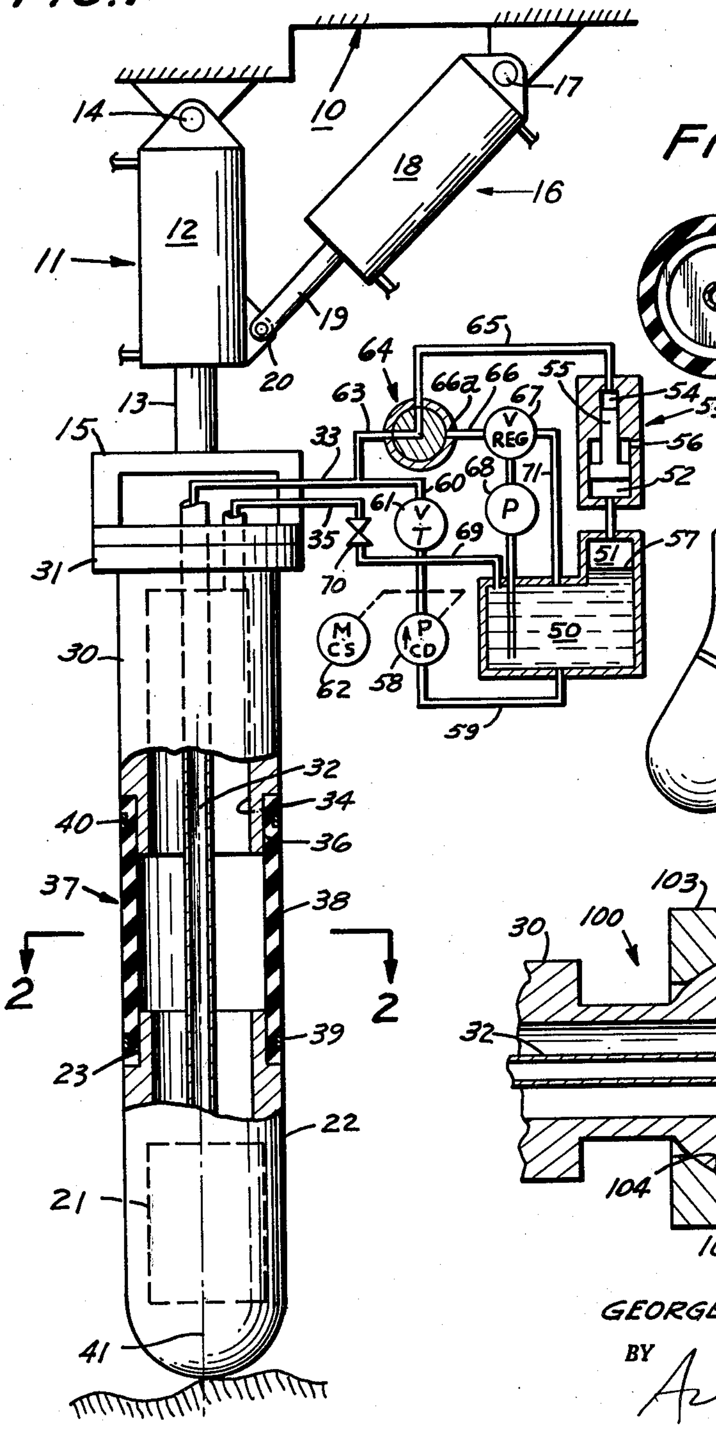


FIG. 2

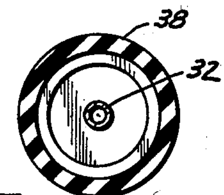


FIG. 3

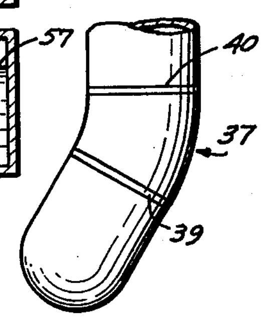
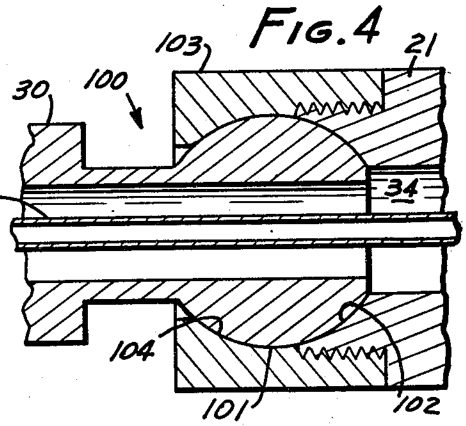


FIG. 4



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VIBRATOR MOUNTING MEANS

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This invention relates to vibrators, and particularly to fluid-powered vibrators for settling and distributing masses of concrete.

Concrete vibrators, depending on their size, generally weigh in the range of between about 15 to 100 lbs., and have diameters between about 1½ to 8 inches. The vibrator unit is usually attached directly to a handle, which handle is grasped by one or more men and thrust by them into the concrete mass in order to vibrate and thereby to settle and distribute it.

In light construction, such as building foundations and walls, pillars, and the like, vibrators are used whose diameter and weight are quite small. They can easily be manipulated by one person. Furthermore, the concrete used in such work is usually quite plastic, and the rock size used in the concrete is relatively small. In view of this, there is no particular difficulty involved in the present technique of manipulating vibrators on light construction. One man can readily handle the vibrator, and the jobs are small and do not take a very long time. It therefore appears that present vibration techniques are generally suitable for this class of concrete work.

However, in heavy concrete work, such as in the building of dams, powerhouses, and other massive structures, it is customary to utilize rubble rock in the concrete, which rock may have dimensions on the order of 6–8 inches. Furthermore, the concrete used is usually very stiff, the water content being held to a minimum. In this class of construction, it is still common practice for the vibrators to be manipulated by hand, even though their weights and diameters are quite large. This is heavy, hard work. Some vibrators of this type can be manipulated by one man working alone, but many require two men. All of them require at least one man, and no means yet has been devised which enables one man to manipulate more than one of such vibrators at a time.

Vibrators for heavy construction work have almost uniformly used compressed air power. This is because compressed air mains are conveniently provided on most construction sites for several purposes, only one of which is to supply power for vibrators. The pressure mains are usually large in diameter and capacity, and are an ordinary and expected expense in such construction. In view of the convenience of this power supply, and the state of the vibrator art, the disadvantages in labor costs and the requirement for heavy manual labor have been tolerated.

There is presently developing a need for vibrators which operate at relatively higher frequencies and with relatively higher output energies and efficiencies than are attainable with compressed air. These are, as a practical matter, attainable only by using high pressure, incompressible liquids for power. However, it is not feasible to provide a separate set of mains and a separate central power plant for supplying pressurized fluids to vibrators alone. Besides, the operating pressure for liquids will be much higher than those for compressed gases, and the mains would have to be heavier and more expensive than presently-used, lower pressure air lines. It is therefore to be anticipated that as liquid-powered vibrators are further developed, there will have to be provided vehicles for carrying pumps to supply the pressurized liquid. Such vehicles will, of course, be moved along the pour, and be closely adjacent to the concrete being vibrated.

The presence of this type of vehicle at the pour gives rise to the opportunity for thrusting the vibrator into the concrete mass by mechanical means rather than by hand, and also of enabling one man mechanically to manipulate more than one vibrator at a time through controls and power units mounted to the vehicle. This offers the opportunity for considerable savings in labor and other expenses.

The use of vehicles requires that there be a relatively flexible coupling between the vibrator and the vehicle, so that vibratory energy is not dissipated in the thrusting means and the vehicle, but instead is largely exerted in the pour by the vibrator. A preferred type of coupling is an inherently flexible tube between the thrusting means and the vibrator. However, this theoretically desirable coupling introduces two basic problems, that of too much flexibility at times, and of too little flexibility at others. These problems principally arise when vibrators are used in vibrating very stiff concrete wherein heavy rubble rock is used.

First, in regular operation, the coupling should be sufficiently flexible that a maximum amount of vibratory energy is exerted in the pour immediately adjacent to the vibrator. A stiff coupling would transmit too much of that energy to the vehicle, which is undesirable both from the standpoint of waste of energy and from wear and tear on the vehicle and its operator. This problem is not important in hand-held vibrators, because the handle is usually quite light in comparison with the vibrator, and the operator holds it loosely, thereby acting himself as a flexible link. However, this solution is not available in a heavy vehicle.

Second, it is necessary to exert considerable end force at times in order to make the vibrator enter into a pour and displace relatively stationary heavy rock which may block its way, or to force its way through a formation when it acts as a drill. If a very flexible coupling is used, the possibility exists that the coupling could completely buckle, thereby either destroying itself or largely eliminating end loads. This condition would tend to limit the utility of vibrators in resistant environments, because while a flexible coupling is often needed, so is considerable stiffness at other times for exerting large end loads. These requirements are contrary to each other, and it is difficult to effect a compromise. Instead, an adjustable, controllable device is called for.

Third, the situation sometimes arises in a pour where a controlled deflection of the vibrator relative to the handle or thrusting means is desirable to enable the vibrator to bypass an obstruction and then to exert sidewardly directed blows on it which would tend to shift the obstruction sidewise. This is effective in moving rock out of the way which cannot be deflected by a pure axial load. When hand-held vibrators are used, this is accomplished merely by tilting the handle, thereby accomplishing the desired forces on the obstruction. However, in deep wells, or in the use of vehicle-mounted vibrators, such a technique is not attainable, because in these the center of rotation of the movement is at the point of attachment, which is far away from the point around which the vibrator should rotate.

In connection with all of these considerations, it should be borne in mind that a conventional vibrator exerts substantially only lateral forces. The only axial forces exerted by it are those which are derived from thrust on the handle.

An object of this invention is to provide a coupling for a vibrator, the rigidity of which is variable in response to the condition the vibrator encounters, and which rigidity in a preferred embodiment automatically varies in response to the load on the vibrator.

This invention is carried out in combination with a vibrator and the handle. It includes an inherently flexible coupling, which is preferably also elastic, and which joins the vibrator and handle in axially-aligned and spaced-apart relationship. Means is provided for exerting fluid pressure within the coupling to place it in axial tension, the flexibility of the coupling thereafter being a function of its internal pressure and of the axial compressive end loading on it. Control of the rigidity of the coupling is derived from the controllability of the internal pressure.

According to one preferred but optional feature of this invention, the pressure inside the coupling is automatically adjusted as a function of the load on the vibrator.

According to still another preferred but optional feature of this invention, the handle is mounted to the vehicle through means whose direction of thrust relative to the vehicle is adjustable, thereby providing means for an operator to select the point and direction of insertion of the vibrator into a pour.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings in which:

FIG. 1 is a side view, partly in cutaway cross-section, showing the presently preferred embodiment of the invention;

FIG. 2 is a cross-section taken at line 2—2 of FIG. 1;

FIG. 3 shows the device of FIG. 1 in one operating position; and

FIG. 4 is a cross-section of still another embodiment of the invention.

FIG. 1 shows the presently preferred embodiment of the invention mounted to a vehicle **10**. An axial thrust means **11** comprising a hydraulic cylinder **12** and extensible piston rod **13** is mounted to the vehicle by hinge **14**. Rod **13** carries a thrust collar **15**.

A direction control means **16** is also attached to the vehicle by a hinge **17** and includes a cylinder **18** and an extensible piston rod **19**. The piston rod is connected to cylinder **12** by another hinge **20**. The axes of all of the hinges are parallel.

Rods **13** and **19** are connected to axially shiftable pistons (not shown) inside their respective cylinders. Means **11** and **16** are provided with hydraulic connections, power units and controls (not shown) which are manipulated by an operator for extending and retracting the respective piston rods. Such hydraulic systems are well known and require no discussion here.

A vibrator **21** includes a housing **22** having a neck end **23**. Any conventional type of vibrators may be used. Vibrators such as those shown in Malan Patents Nos. 2,187,-088; 2,743,090; and 2,891,775 are quite suitable. They are all provided with central pressure ports and co-axial outer exhaust ports.

A handle **30** includes a thrust collar **31** which abuts and is attached to thrust collar **15**. The handle includes a central flexible pressure line **32** adapted to be connected to a source of pressure through line **33** and to the pressure port of the vibrator. It is surrounded by co-axial exhaust line **34** and to an exhaust line **35**. The handle also includes a reduced neck end **36**.

A coupling generally designated by numeral **37** comprises a tube **38**, which surrounds and is attached to neck ends **23** and **36** by bands **39**, **40** or any other suitable means. The tube spaces the neck ends apart along axis **41** of the vibrator, and joins the two. The central exhaust line is not intended to provide any structural support between the handle and vibrator. The only substantial structural support for the vibrator from the handle is intended to be exerted by the coupling. The coupling is inherently flexible, but stiff enough to resist bending. It may, for example, have an axial length of about 7 inches with a free length between the neck ends of about 3 to 4 inches. For a 6-inch diameter vibrator operating at about 1000 p.s.i.g., the wall thickness of this tube may be about ¾ to 1 inch and may conveniently be made of rubber. The inside free length of the tube is exposed to exhaust pressure from the vibrator. This pressure tends to thrust the handle and vibrator apart, placing the tube in axial tension. It also tends to apply expansive forces thereon.

The properties and dimensions of the tube will be selected to resist ready bending, but to be inherently flexible. Axis **41** is the common axis of the handle, coupling and vibrator when they are at rest. The thrust control means and the direction control means are adjusted to exert axial thrust to force the vibrator in the desired direction. The vibrator is placed in operation by applying pressure to the pressure lines, and in operation exerts unbalanced lateral forces. Obviously there will be some side deflection of the vibrator relative to the axis of the handle whenever the vibrator operates, because the coupling is inherently flexible, and this is desirable in order to exert maximum energy in the pour, and minimum energy in the handle and on the vehicle. However, the inherent flexibility of the tube is lessened by axial tension to which the tube is subjected by the fluid pressure, and this stiffens the coupling when stiffness is desired. Conversely, lessening of the axial tension by an axial compression force lessens the rigidity and renders the coupling more flexible.

The control system for both automatically and manually regulating the flexibility, and conversely the rigidity, of the coupling is shown in FIG. 1. A closed, hermetically-sealed reservoir **50** has a pressure dome **51** which is connected to a first chamber **52** of a differential-pressure accumulator **53**. Its second chamber **54** has a lesser cross-sectional area than the first chamber. A differential piston **55** is slidedly fitted in the two chambers. A vent port **56** is formed through the accumulator wall just above the region traversed by the lower portion of the piston to vent the same.

The hydraulic system is closed, and not vented to atmosphere in order that the exhaust pressure may be regulated. Liquid **57** does not entirely fill the pressure dome, but leaves a region therein above the liquid, which is occupied by a gas. This region is connected to the first chamber of the accumulator. The purpose of the differential pressure accumulator is to step down the pressure from the pump, from which the accumulator's basic pressure is derived.

A constant delivery pump **58** withdraws liquid from the reservoir and pumps it from line **59** to line **60**, line **60** being connected to line **33**. A throttle valve **61** is provided in line **60**. A constant speed motor **62** drives pump **58**. This motor and pump deliver a predetermined volume of liquid per unit time, but the absolute pressure at which the liquid is delivered depends upon the back pressure in the system and on the demand of the vibrator.

Line **60** is side-tapped by side **63** which discharges into one port of a selector valve **64**. Line **65** connects another port of the selector valve to the second chamber of the accumulator.

Line **66** interconnects still another port ***66a*** of the selector valve to the reservoir through a bleed-type regulator **67** and a pump **68**. The selector valve can be set to disconnect all of its lines from each other, or to connect lines **60** and **65** or lines **65** and **66**.

Line **69** connects exhaust line **35** to the reservoir. A variable restrictor **70** may, if desired, be placed in line **69**.

FIG. 4 illustrates the broad scope of the invention, as applicable to flexible couplings in general, whether also elastic or not, so long as the coupling can be placed in axial tension which is opposable by axial compressive forces. Handle **30** and vibrator **21** are shown joined by a coupling **100**, which is a ball joint. Pressure line **32** and exhaust line **34** pass through the coupling.

The handle neck has been modified by a ball **101**, and the vibrator neck has been modified by a seat **102**. A retainer **103** has a seat **104** which is threaded onto the neck, the ball being trapped between seats **102** and **104**. This ball joint is inherently flexible around the center of the ball. In accordance with conventional construction, a very small clearance is left between the seats and the ball to permit these surfaces to be lubricated. Conventional seals (not shown) may be provided between the seats and ball surfaces to minimize leakage and confine the lubricant, if desired.

The operation of the device of FIG. 1 will now be described. Rotary devices such as vibrators require a given volume-rate of flow per unit time in order to operate at a given frequency. They will operate at a frequency determined by the rate of flow, although the working pressure may vary. The pressure drop across a vibrator (that is the differential pressure between the pressure and exhaust lines) will increase as the load on the vibrator increases, and decrease as the load decreases. In general, the lightest load in vibrators of this class will occur when the vibrator is running free in the air, and the heaviest load occurs when the vibrator is placed in a stiff, but still plastic medium, such as stiff liquid concrete of low water content, but not in the condition in which it is firmly grasped by relatively rigid and immovable rock.

In order for a given volume of fluid to be pumped through the vibrator when it is under load, the inlet pressure must be raised. With the constant speed motor and constant delivery pump shown in FIG. 1, this merely places a heavier load on the motor and its energy supply. However, the pressure generated by the pump will rise.

Furthermore, in a closed unvented system such as that shown in FIG. 1, the inlet pressure differs from reservoir pressure by an increment equal to the pressure drop and line loss. It follows that exhaust pressure relative to atmosphere can be regulated in order to control the pressure inside the coupling, which in turn raises the inlet pressure, but leaves the differential pressure between inlet and exhaust lines substantially unaffected. The pressure in the exhaust line thereby is variable with the load on the vibrator, and by the back pressure exerted from the reservoir. This latter provides means for controlling the flexibility and rigidity of the coupling.

Assume that pump **58** is running so as to deliver its prescribed volume, and that the throttle valve is wide open. The selector valve is set to connect lines **33**, **60** and **65**. This sets the reservoir pressure (which is the pump inlet pressure and coupling pressure) at a lower value than pump output pressure, this value being determined by the ratio between the cross-sectional areas of the chambers. Thus, the back pressure in the reservoir and on the exhaust side of the vibrator, is established by the output pressure of pump **61**.

Assuming that the vibrator is running at a light load, the pressure difference between lines **32** and **34** is at a value toward its minimum, and the system adjusts itself accordingly, the pump output pressure also being at a working minimum to supply the pressure differential required. Because the differential is small, the pump output pressure is relatively small, and so is the pressure inside the coupling. Now when the vibrator is placed under a heavier load, the differential pressure across it, that is, the working pressure to force a constant volume of fluid per unit time, through the vibrator increases. Therefore the output pressure of the pump increases, a heavier load being placed on motor **62**.

An increase in the output pressure raises the accumulator, reservoir, and coupling pressure, and the pump output pressure adjusts itself accordingly. The important result of this is an increase in the back pressure in the coupling.

A similar result could have been secured by adjusting restrictor **70**, but it is uneconomical to use restrictor valves in this type of circuit merely to control pressures, because of the amount of work it takes to pump fluid through them. The accumulator adjusts the pressures without wasting energy. Therefore, restrictor **70** is not to be preferred, and if present is usually kept wide open.

When the coupling pressure increases, its stiffness increases, and it will be noted that this occurred in the above example when the load increased. An increased load might reflect the meeting of an end-loading obstruction of the type a strong axial push could overcome, such as in drilling operations, for example. This coupling, which is relatively flexible in normal running operation, becomes stiffer with increased load, which is one useful way to operate it.

Another mode of operation is to preset the reservoir or back pressure to some value, such as by connecting lines **65** and **66**, and using pump **68** and bleed-type regulator **67** to maintain a constant pressure in line **65**. The regulator shown maintains pressure in line **66**, and discharges excess fluid through line **71** to the reservoir. With this arrangement, the coupling has a preset pressure level, and any end load will oppose this level, thereby rendering the coupling more, instead of less, flexible, as shown in FIG. 3. The difference here is that the elongating force is constant, and can be overcome by the compressive force to render the coupling more flexible, while in the previous example, an increasing load made the coupling more rigid. Thus, the coupling is made versatile to cope with various situations. When a more rigid coupling is needed in order to axially pierce a region, it is available. When a more flexible coupling is needed to provide for side flailing, that too is available. In both arrangements, a normal flexibility is available for normal operations.

When the ball joint is provided, the results are the same. The additional or lesser loadings result in greater or lesser flexibility. Furthermore, the elongating forces tend to overcome the compressive forces, thereby enabling lubrication to reach the adjacent surfaces, thereby overcoming the cause of many ball joint failures, i.e. lack of lubrication at strongly forced-together abutting, relatively sliding surfaces. The ball joint is, therefore, a mechanical equivalent of the flexible but elastic tube in many important respects.

The term "vehicle" as used herein is not intended to be limited to any particular class of mobile element. In fact, the vehicle might be skid-mounted, wheel-mounted, or track-mounted, or merely stand on a base. The term "vehicle" is intended to define a supporting structure which is subject to being moved, either under its power, or by being lifted or shoved around by any means, without limitation as to the exact nature of the supporting means or of the motive means.

This device thereby provides a convenient means whereby a vibrator may be vehicle-mounted and rendered more able to move into resistive bodies.

This invention is not to be limited by the embodiment shown in the drawings and described in the description which is given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. In combination: a vibrator having an inlet and an exhaust outlet; a handle; and a coupling for mounting the vibrator to the handle, said handle, coupling and vibrator having coincident longitudinal axes, and the vibrator being adapted to exert unbalanced lateral vibratory forces, the coupling joining the vibrator and handle, and holding them in axially spaced-apart relationship, the coupling comprising a tube of inherently flexible and elastic material; pressure means for supplying fluid under pressure to the vibrator inlet to operate the same; and back-pressure means in fluid connection between the coupling and the pressure means, whereby the vibrator and the coupling are in series connection in a fluid circuit, pressure in the coupling being variable as a function of the differential pressure between the inlet and the exhaust outlet.

2. A combination according to claim 1 in which the pressure means, vibrator, back-pressure means and coupling are formed in a closed, unvented system.

3. In combination: a vehicle; a vibrator having an inlet

and as exhaust outlet; a handle; a coupling for mounting the vibrator to the handle; axial thrust means attached to the handle and to the vehicle; direction control means attached to the vehicle and to the axial thrust means, the handle, coupling, vibrator and axial thrust means having coincident longitudinal axes, the vibrator being adapted to exert unbalanced, lateral vibratory forces, the coupling joining the vibrator and handle, and holding them in axially spaced-apart relationship, the coupling comprising a tube of inherently flexible and elastic material; pressure means for supplying fluid under pressure to the vibrator inlet to operate the same; and back pressure means in fluid connection between the coupling and the pressure means, whereby the vibrator and the coupling are in series connection in a fluid circuit, pressure in the coupling being variable as a function of the differential pressure between the inlet and the exhaust outlet; the axial thrust means being adapted to move the vibrator and handle in axial directions, and the direction control means being adapted to select that direction.

4. A combination according to claim 3 in which the axial thrust means and direction control means each comprises a piston-cylinder assembly.

5. A combination according to claim 3 in which said pressure means is adjustable to vary the said pressure.

6. A combination according to claim 3 in which said pressure means is a closed unvented liquid system including a constant delivery pump, back pressure on the system constituting the fluid pressure in the tube.

7. A vibrator system of adjustable rigidity, comprising: a vibrator having a fluid pressure inlet and an exhaust outlet; a handle; a coupling for mounting the vibrator to the handle, said handle, coupling and vibrator having coincident longitudinal axes, and the vibrator being adapted to exert unbalanced lateral vibratory forces, the coupling joining the vibrator and handle, and holding them in axially spaced-apart relationship, the coupling comprising a tube of inherently flexible and elastic material; a pressure source; a pressure line connecting the pressure source to the fluid pressure inlet of the vibrator; a closed, unvented reservoir; an exhaust line which includes the tube connecting the exhaust outlet to the reservoir; the pressure source comprising a constant delivery pump withdrawing fluid from the reservoir; and means for raising the reservoir pressure as a function of raising pump output pressure.

8. A vibrator system of adjustable rigidity comprising: a vibrator having a fluid pressure inlet and an exhaust outlet; a handle; a coupling for mounting the vibrator to the handle, said handle, coupling and vibrator having coincidence longitudinal axes, and the vibrator being adapted to exert unbalanced lateral vibratory forces, the coupling joining the vibrator and handle, and holding them in axially spaced relationship, the coupling comprising a tube of inherently flexible and elastic material; a pressure source; a pressure line connecting the pressure source to the fluid pressure inlet of the vibrator; a closed, unvented reservoir; an exhaust line which includes the tube connecting the exhaust outlet to the reservoir; the pressure source comprising a constant delivery pump withdrawing fluid from the reservoir; and means comprising an accumulator, one side of which is connected to the pump outlet pressure, and the other side of which is connected to the reservoir, for raising the reservoir pressure as a function of raising pump output pressure.

9. A vibrator system according to claim 8 in which the accumulator is a differential pressure type, whereby pressure maintained by it in the reservoir is less than pump output pressure.

10. A vibrator system according to claim 8 in which an alternate, variable pressure source is provided to adjust the accumulator pressure independently of the pump output pressure, and in which a selector valve is provided to select between pump output pressure and said alternate source.

11. A vibrator system of adjustable rigidity, comprising: a vibrator having a fluid pressure inlet and an exhaust outlet; a handle; a coupling for mounting the vibrator to the handle, said handle, coupling and vibrator having coincident longitudinal axes, and the vibrator being adapted to exert unbalanced lateral vibratory forces, the coupling joining the vibrator and handle, and holding them in axially spaced-apart relationship, the coupling comprising an inherently flexible ball joint; a pressure source; a pressure line connecting the pressure source to the fluid pressure inlet of the vibrator; a closed, unvented reservoir; an exhaust line which includes the ball joint connecting the exhaust outlet to the reservoir; the pressure source comprising a constant-delivery pump withdrawing fluid from the reservoir; and means for raising the reservoir pressure as a function of raising pump output pressure.

12. In combination: a vibrator; a handle; and a coupling for mounting the vibrator to the handle, said handle, coupling and vibrator having coincident longitudinal axes, and the vibrator being adapted to exert unbalanced lateral vibratory forces, the coupling joining the vibrator and handle, and holding them in axially spaced-apart relationship, the coupling comprising an inherently flexible ball joint; and means for exerting fluid pressure within the ball joint to place it in axial tension, whereby the ball joint is inherently stiffer and tends to resist bending, compressive end-loading tending to overcome at least some of the axial tension and render the ball joint less rigid.

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