April 10, 1962 C. LEAVELL 3,028,840

VIBRATIONLESS PERCUSSIVE TOOL

Filed June 15, 1960 2 Sheets-Sheet 1

FIG. 1

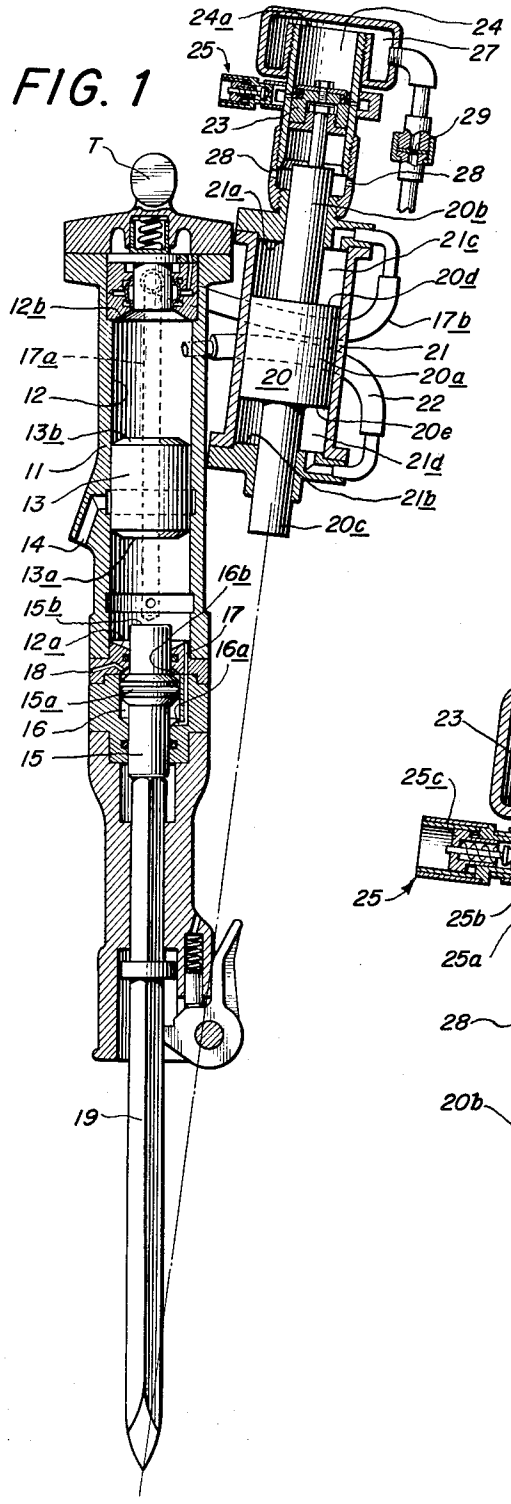
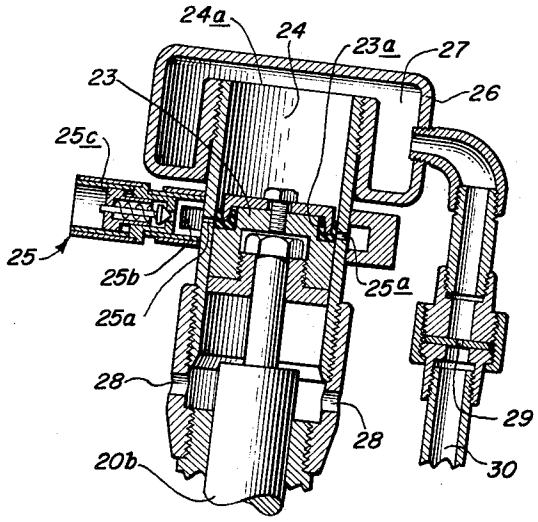


FIG. 2



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FIG. 3

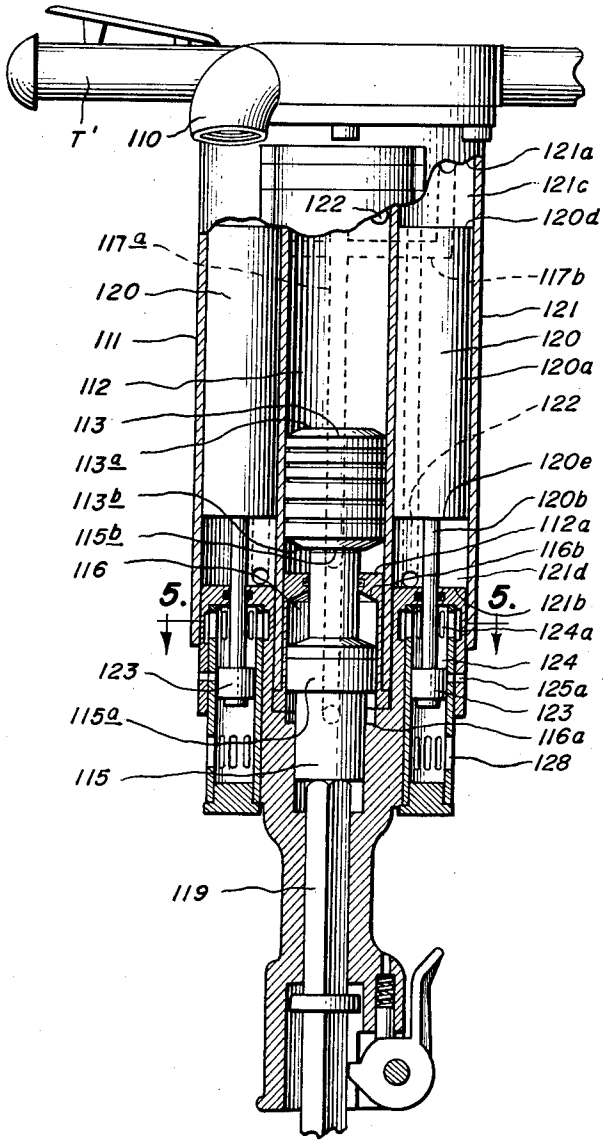


FIG. 4

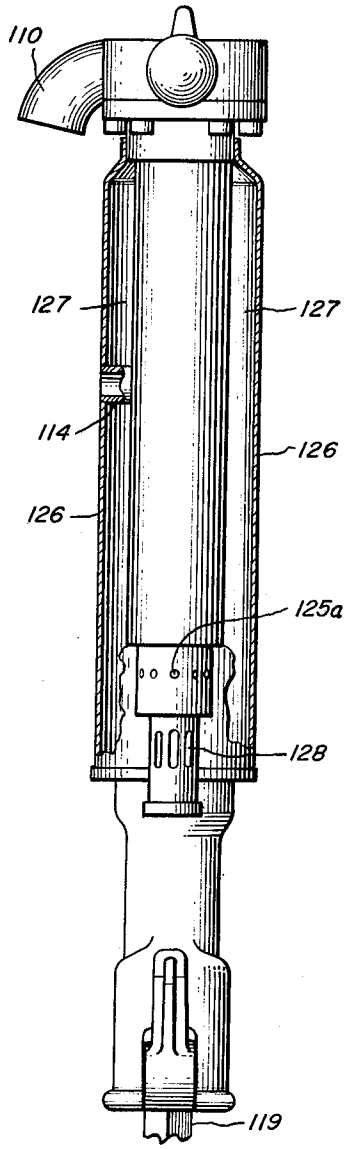
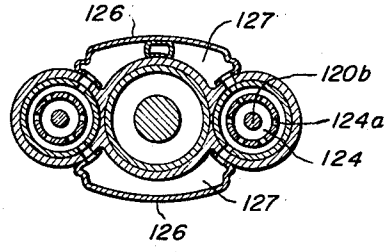


FIG. 5



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3,028,840

VIBRATIONLESS PERCUSSIVE TOOL

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15 Claims. (Cl. 121—13)

This invention relates to gas-actuated percussive tools as, for example, pneumatic paving breakers, and is particularly concerned with improving such tools by making the operation thereof substantially vibrationless.

Considering the paving breaker as an exemplification of environments in which the invention has utility, the structural composition thereof includes a casing defining an axially extending cylinder therein, a hammer or piston reciprocable within the cylinder, and a steel spike or work member slidably carried by the casing for limited axial movement with respect thereto and which is adapted to receive impact from the hammer (usually through an anvil or tappet interposed therebetween) at one end of the reciprocatory stroke thereof. The impact transmitted by the hammer to the spike is delivered thereby to a concrete slab or other work material to break or demolish the same, and the hammer is reciprocated within its cylinder by the alternate application of pressure fluid to the opposite ends thereof.

In the usual paving breaker, the charges of compressed air alternately admitted into the opposite ends of the cylinder to respectively reciprocate the hammer in directions toward and away from the spike are each reactively applied against transverse surfaces defining the end closures of the cylinder, and as a consequence the casing is moved or vibrated in opposite directions along the axis of reciprocation of the hammer. In many tool structures, the hammer is reciprocated through approximately 1,200 cycles each minute, and consequently, the pressure forces reacting alternately against opposite ends of the casing cylinder introduce a violent and objectionable vibration into the casing. Thus, in the usual paving breaker, the compressed air pressure force reacting alternately against opposite ends of the casing cylinder defines "connecting structure" accomplishing a necessary transmission of force between the hammer which is a "desirably or unavoidably vibrating body" and the casing which is a "body in which the occurrence of vibration is objectionable."

The present invention is concerned with eliminating vibration ordinarily introduced into the casing of such a percussive tool by the pressure forces reactively applied to the casing cylinder in actuating the hammer by counterbalancing such reactive forces with the simultaneous application to the casing of substantially equal and opposite pressure forces. Such pressure-force counterbalancing system includes a hermetic barrier that, in the specific structure considered in detail herein, takes the form of an oscillator or oscillatory mass member that reciprocates within a cylinder therefor; and it has been found that in certain situations, random and irregular recoil forces are fed into the tool structure through the steel spike as a result of the non-homogenity of the slab being penetrated thereby, and such recoil forces tend to cause the oscillator to migrate toward one end of its cylinder and to impact the end closure thereof which is an undesirable condition since it would reintroduce vibration into the casing. Therefore, the present invention is also concerned with avoiding such a condition of impact relation between the oscillator and end of its cylinder, and does so by stablizing the mean position of the oscillator with an automatic control system that includes a pneumatic column operative between the oscillator structure and one end of its cylinder, which pneumatic column defines a force-transmitting linkage structure coupling the necessarily vibrating oscillator and cylinder therefor

in which the presence of vibration is objectionable, that also includes an arrangement for maintaining the force defined by such pneumatic column relatively constant during any one cycle of reciprocation of the oscillator, and that further includes pneumatic feedback means for regulatively adjusting the value of such relatively constant force during a plurality of reciprocations of the oscillator to positionally stabilize the same as aforesaid in order to maintain it in a condition of intermediacy relative to the ends of its cylinder.

Embodiments of the invention are illustrated in the accompanying drawings, in which—

FIGURE 1 is a vertical sectional view of a pneumatic percussive tool embodying the invention; FIGURE 2 is an enlarged, broken vertical sectional view of a portion of the tool illustrated in FIGURE 1; FIGURE 3 is a partial vertical sectional view of a modified pneumatic percussive tool embodying the invention; FIGURE 4 is a side view in elevation of the tool shown in FIGURE 3, and in which portions thereof are broken away and are illustrated in section; and FIGURE 5 is a transverse sectional view taken along the line 5—5 of FIGURE 3.

The tool structure illustrated in FIGURE 1 is a pneumatically-actuated paving breaker, and to a great extent embodies a conventional vibratory tool. Thus, the structure comprises a casing **11** providing a main cylinder **12** having therein a pneumatically-actuated free-piston hammer or mass member **13**. The casing **11** is equipped with handles T, and provides an exhaust port or passage **14** to atmosphere communicating with the cylinder **12** intermediate the ends thereof. The upper end of the cylinder **12** is occupied by a conventional valve composition operative to direct the flow of gaseous fluid (such as compressed air) alternately to the lower and upper end portions of the cylinder to energize the reciprocatory cycle of the hammer **13** by selectively applying upwardly and downwardly active axial pressure forces alternately to the lower surface **13***a* and to the upper surface **13***b* thereof.

The bottom cylinder head area facing the lower surface **13***a* of the hammer consists only of the upwardly facing surface of the annular shoulder defined around and having a sliding relation with the upper end portion of the anvil element **15**. The top cylinder head area facing the surface **13***b* of the hammer is made up of the downwardly facing surfaces of the valve composition occupying the upper end of the cylinder. For identification, the annular bottom and aggregate top cylinder head surface areas are respectively denoted with the numbers **12***a* and **12***b*.

The anvil **15** has an enlarged seal-equipped intermediate portion **15***a* that reciprocates within an anvil chamber **16**, and the anvil chamber has lower and upper end closures **16***a* and **16***b* which respectively engage the lower and upper stems of the anvil in sealing relation therewith, the latter of which extends into the cylinder **12** and has an upper surface **15***b* adapted to be struck by the hammer **13**. The lower end portion of the anvil chamber **16** adjacent the closure **16***a* thereof is connected with the lower end of the cylinder **12** by a passage **17**, and therefore the lower end portions of the anvil chamber and cylinder are pressurized simultaneously.

The upper end portion of the anvil chamber **16** adjacent the end closure **16***b* thereof is exhausted to atmosphere through a passage **18**, and the lower end portion of the anvil which extends through the surface **16***a* and is sealingly related therewith is adapted to rest upon the upper inner end of a steel spike or work member **19** slidably carried by the casing **11** for limited axial movement with respect thereto. Ordinarily, the spike **19** will have a pointed lower end, and may be equipped intermediate the ends thereof with an outwardly projecting annular

flange cooperative with the usual retainer element carried by the casing for removably constraining the spike within the casing.

In operation of the structural arrangement thus far described, and assuming initially a parts configuration in which the hammer **13** is in abutment with the upper surface **15***b* of the anvil, a charge of compressed air will be directed by the valve composition into the lower end portion of the cylinder **12** through a passage **17***a* in the tool casing. Such charge of air acting upwardly upon the bottom surface **13***a* of the hammer will reciprocate the hammer upwardly through the return stroke thereof. Simultaneously, however, a reactive pressure force acting downwardly upon the lower reaction surface (the terms "lower reaction surface" and "upper reaction surface" respectively designating the total upwardly facing and total downwardly facing surface areas reactively pressurized by the charges of air reciprocating the hammer, and which respectively transmit downwardly directed and upwardly directed axial forces to the casing; and which in the subject structure respectively comprise the aforesaid surfaces **12***a* and **16***a*, and the aforesaid surface **12***b*) will cause the casing **11** to vibrate downwardly as the hammer **13** is reciprocated through its return stroke, and such reactive pressure force is applied to the casing until the upwardly moving hammer passes the exhaust port **14**, at which time the lower end portion of the cylinder **12** as well as the lower end portion of the anvil chamber **16** will be exhausted to atmosphere.

As the hammer **13** approaches the upper end closure of the cylinder **12**, the valve composition directs a charge of compressed air into the upper end portion of the cylinder, and the resulting pressure force acting downwardly upon the hammer reciprocates it into impact with the surface **15***b* of the anvil which delivers such impact to the spike **19**. Simultaneously, however, such charge of compressed air exerts an upwardly directed reactive force against the upper reaction surface of the casing or of the cylinder defined thereby which vibrates the casing upwardly, and such reaction force is applied to the casing until the downwardly moving hammer **13** passes the exhaust port **14**, at which time the upper end portion of the cylinder **12** is exhausted to atmosphere.

Since the reciprocatory frequency of the hammer in a conventional vibratory tool may approach and exceed 1,200 cycles per minute, the casing thereof would objectionably vibrate longitudinally at the same rapid rate; but with reference to the present invention, the aforementioned counterbalancing system is effective to nullify such reactive pressure forces that normally cause such casing vibration; and the structural arrangement accomplishing this counterbalancing in the tool of FIGURE 1 will now be described.

Operative externally of the main tool casing **11** is an oscillator **20** which is reciprocable in its own cylinder or support structure **21** secured to the main tool casing so as to be rigidly related thereto. This oscillator element comprises a massive body or piston portion **20***a* having upper and lower stems **20***b* and **20***c* extending coaxially from the upper and lower surfaces of such piston portion. These surfaces form annular shoulders or piston surfaces **20***d* and **20***e*, and are reciprocable relative to and in coaxial relation with the respectively opposing annular cylinder head surfaces **21***a* and **21***b* carried by the casing (respectively denoted hereinafter as upper and lower counterbalancing surfaces).

It will be observed in the drawings that the oscillator cylinder **21**, and more particularly the variable-volume annular space **21***c* thereof defined between the upper piston and cylinder head surfaces **20***d* and **21***a*, connects by a tube or passageway **17***b* and the longitudinal passageway **17***a* to the variable-volume space under the hammer **13** in the main cylinder **12**. Similarly, the lower variable-volume space **21***d* in the oscillator cylinder and the variable-volume space above the hammer **13** in the main cylinder **12** are connected by a tube or passageway **22**.

Before describing the operation of the tool with reference to the pressure-force counterbalancing system, it should be noted that the axially projected areas of the upper reaction surface **12***b* in the main cylinder **12** and the lower counter-balancing surface **21***b* in the oscillator cylinder **21** are substantially equal, and similarly, that the axially projected areas of the lower reaction surface **12***a* plus **16***a* in the main cylinder **12** and the upper counterbalancing surface **21***a* of the oscillator cylinder **21** are substantially equal, for such conditions of equality provide the most ideal functioning of the pressure-force counterbalancing system. In the specific tool structure considered, an additional equality is present in that the axially projected areas of the lower and upper surfaces **13***a* and **13***b* of the hammer are substantially equal, and approximately equal thereto are the axially projected areas of the lower and upper reaction surfaces.

Considering again the operation of the tool, and assuming the same initial condition thereof, the admission of a charge of compressed air beneath the hammer to reciprocate the same upwardly, and which necessarily applies a downwardly directed reactive pressure force against the casing, will simultaneously apply an upwardly directed pressure force against the casing or, more specifically, against the upper counterbalancing surface **21***a* thereof, because of the interconnection of the upper end portion **21***c* of the oscillator cylinder with the lower end of the cylinder **12** through the conduit **17***b* and passage **17***a*. Since the axially projected areas of the upper counterbalancing surface **21***a* and the lower reaction surface are approximately equal, the upwardly and downwardly directed pressure forces applied simultaneously to the casing are substantially equal and, therefore, counterbalance and effectively eliminate downward vibratory movement of the casing which would otherwise result from the admission of compressed air into the lower end portion of the cylinder **12** to reciprocate the hammer **13** upwardly.

Correspondingly, when a charge of air is introduced into the upper end portion of the cylinder **12** to reciprocate the hammer **13** downwardly, the reactive force acting against the upper reaction surface of the casing and which tends to vibrate the same upwardly is counterbalanced by the simultaneous application of a downwardly directed pressure force upon the casing or, more specifically, against the lower counterbalancing surface **21***b* because of the interconnection of the lower end portion **21***d* of the oscillator cylinder with the upper end portion of the cylinder **12** through the tube **22**. Since the axially projected areas of the upper reaction surface of the cylinder **12** and the lower counterbalancing surface **21***b* of the oscillator are substantially equal, the reactive pressure force which would otherwise vibrate the casing **11** upwardly is effectively counterbalanced.

It will be noted in the tool of FIGURE 1 that the oscillator composition is attached as a unit to the casing **11** of a conventional paving breaker, and this implies the use of such composition as an accessory for ordinary vibratory-type paving breakers for the purpose of converting such tools for vibrationless performance. Such attachment cannot be practically achieved by placing the type of oscillator structure shown above the handle and backhead element of the tool, for such positioning would increase the length of the tool to the point that an operator could not lean over it conveniently to apply downpush thereto, and therefore the oscillator structure is best applied alongside of the casing.

However, if in such placement the reciprocatory axes of the hammer **13** and oscillator **20** are made parallel, the necessary displacement therebetween defines a laterally extending or radial lever arm equal in length to the distance between the axes and operative relative to the fulcrum or pivot structure established by the seating of the

spike point in the pit made thereby in the stationary concrete slab. As a consequence, the tool will tend to vibrate angularly about such fulcrum. This tendency toward angular vibration is eliminated by orienting the oscillator and hammer axes as shown in FIGURE 1, which reduces such lever arm to an effective length of zero by providing that both the hammer and oscillator axes contain the fulcrum or pivot defined by the spike point. This condition may be termed the copivotal relation of the hammer and oscillator axes, and the excellence of the results obtained depends upon the limitation of the copivotal angle (that is, the angle defined between the hammer and oscillator axes) to a sufficiently small value so that the cosine thereof approximates unity.

It will be apparent that the counterbalancing action requires phases of operation during which each of the surfaces 21*a* and 21*b* is pressurized without the other of these surfaces being simultaneously pressurized; and in terms of structure, this requirement defines the condition that the oscillator 20 be a hermetic barrier interposed between the surfaces 21*a* and 21*b* to maintain pneumatic isolation therebetween. It is further evident that the oscillator 20 in this environment is necessarily subjected to reversing forces of a substantial order of magnitude, and must be supported within its cylinder with a positional stability such that it is maintained intermediate the ends of the cylinder in a non-impacting relation therewith so as not to transmit any uncounterbalanced variable forces to the casing. The structural arrangement for accomplishing this condition of positional stability includes a piston 23 extending upwardly from the top of the stem 20*b* of the oscillator. A cylinder 24 that slidably receives piston 23 is provided with escape holes 25*a* permitting the cylinder to exhaust to atmosphere, and the uncapped upper end 24*a* of the cylinder opens into an annular tank 26 defining a "constant pressure" space 27 therein. The space below the bottom surface of the piston 23 is maintained at atmospheric pressure through the agency of ports 28.

The escape holes 25*a* lead into an annular space 25*b* defined around the cylinder 24, and the escaping air collected in this annular space is exhausted to atmosphere through a spring biased valve 25*c*. This valve and annular space are optional and function to prevent the pressure in the cylinder 24 and constant pressure space 27 from dropping below a relatively low predetermined value (for example, 3 pounds per square inch gauge) sufficient to hold the oscillator 20 in its downmost position when the tool is not running, and prevents the first upward oscillations of the oscillator from carrying it into impact with its own upper cylinder head 21*a*. As seen in FIGURE 2, a restricted orifice 29 is provided in a plate extending transversely across the infeed line 30, and supplies air to the aforesaid constant pressure space 27. The escape holes 25*a*, collection space 25*b* and valve 25*c* together comprise the exhaust system for the space 27, and for convenience such system in its entirety is designated with the numeral 25. This exhaust system 25 together with the restricted infeed orifice 29 and piston 23 acting cooperatively therewith in a manner described hereinafter, comprise the aforementioned automatic control system whereby the aforesaid condition of positional stability is imposed upon the oscillator 20.

This composite automatic control system is pneumatically energized by a high pressure inflow through the restricted orifice 29, which generally effects a substantial pressure drop, and into and through the composite space consisting of the constant pressure space 27 and space in the upper portion of the cylinder 24, to commence its escape therefrom to atmosphere, whenever the position of the piston seal 23*a* permits, through the small ports 25*a* which collectively comprise a considerably greater cross-sectional area than that of the inflow orifice 29. It may be noted that the cylinder 24 need not necessarily have an open upper end as shown, which is the ideal condition, but any lesser opening connecting the cylinder and constant pressure space 27 should be sufficiently large so that substantially no pressure gradients will develop in the reciprocating air flow between the upper end portion of the cylinder and the constant pressure space.

The composite automatic control system is utilized to keep the oscillator from striking the cylinder heads 21*a* and 21*b*, and the principal tendency of the oscillator in this respect is to rise during its oscillatory motion toward a condition of impact with the upper cylinder head 21*a*—which may be explained in terms of the forces acting on the hammer 13 as follows: First, the only forces acting downwardly upon the hammer are the intermittently effective pneumatic forces (omitting the force of gravity which is negligible and ineffective when the tool is operated in a horizontal position). Secondly, intermittently effective pneumatic forces act upwardly upon the hammer, but in addition there is a mechanical force which assists such upwardly acting pneumatic forces in urging the hammer upwardly. Such mechanical force is caused by the impact relation of the hammer and anvil for when the hammer strikes the anvil, the anvil is urged downwardly for an extremely brief interval by an extremely large force which may approach a value of 50,000 pounds. Action and reaction being equal, the hammer is urged upwardly by this very large force.

These considerations establish that the average value of the pneumatic forces acting upwardly on the hammer must be less than the average value of the pneumatic forces acting downwardly thereon inasmuch as the mean position of the hammer remains fairly fixed during operation of the tool; for, since the hammer does not migrate beyond the limits of its cylinder during operation of the tool, it is necessarily implied that the respective average values of all of the forces acting downwardly on the hammer and of all of the forces acting upwardly thereagainst are very closely equal; whence, more specifically, the average value of the total pneumatic and mechanical force acting upwardly upon the hammer must be almost exactly equal to the average value of the pneumatic force acting downwardly thereagainst; so that it follows that the average value of the pneumatic forces acting upwardly against the hammer must be substantially less than the average value of the pneumatic forces acting downwardly thereon.

Since the space 21*c* above the oscillator is in open communication with the space in the cylinder 12 below the hammer, and the space 21*d* below the oscillator is in open communication with the space in the cylinder above the hammer, the average values of the pressures in these oscillator spaces are substantially equal respectively to the average values of the pressures in the cylinder spaces below and above the hammer. Therefore, in consequence of the foregoing argument, there is an effective preponderance of the average value of the pneumatic force acting upwardly upon the oscillator over the average value of the pneumatic force acting downwardly thereon, which imposes upon the oscillator a continuous tendency to rise which, if not arrested, would reintroduce vibration into the casing 11 since the oscillator would pound against the upper cylinder head surface 21*a*.

To prevent this, an additional surface is employed on the oscillator against which sufficient pressure can be developed to hold the oscillator down whereby it can be made to operate over a reciprocatory range intermediate the ends of its maximum stroke so that it will not strike the cylinder heads 21*a* and 21*b* respectively above and below the oscillator, and such additional surface is the top surface of the piston 23 in the automatic control system comprising the previously specified elements 29, 25*a*, 25*b*, 25*c* and 23*a*, together with the piston 23 and the continuous space within the tank 26 and cylinder 24.

This composite structure operates so that if the oscillator 20 starts to oscillate about a mean position which is too high, thereby causing a danger of impact with the cylinder head 21*a*, the piston 23 will rise upwardly with

the oscillator and will close the escape holes **25***a*, as seen best in FIGURE 2. The establishment of this condition prevents escape of air from the total space above the piston **23**, and the compressed air continuously fed into this space through the restricted inlet orifice **29** will cause the pressure therein to increase in value and, as a consequence, the oscillator **20** will be urged downwardly with a steadily increasing pressure force until it reaches a position in which the escape holes **25***a* are uncovered during at least part of the reciprocatory cycle of the oscillator. If the oscillator is forced downwardly until the escape holes remain uncovered during the entire reciprocatory cycle of the oscillator, the pressure within the space above the piston **23** will drop rapidly. The pressure will then continue to decrease until it no longer gives sufficient assistance to the pressure force acting on the surface **20***d* of the oscillator to hold it in such lower position, and the oscillator will then start to rise toward its stable intermediate location in which the escape holes are covered during a part of each cycle of reciprocation.

Experience has shown that migration of the oscillator such that the escape holes are either closed or open during the entire reciprocatory cycle of the oscillator is held to brief durations, and there is therefore a strong tendency for the oscillator to remain stabilized in an intermediate location wherein the escape holes are closed during only a part of each reciprocatory cycle of the oscillator. It should be understood that sucessful operation of the automatic control in this partciular structural design requires compensatory changes in the pressure acting downwardly on the surface of the piston **23** to be effected quickly since the average value of the mechanical impact force reactively delivered during any relatively short interval by the anvil **14** upwardly against the bottom of the hammer **13** is related to the strength and elastic properties of the concrete being encountered by the spike **19** during that same interval, and such qualities of the concrete are subject to rapid variations. It will be apparent that the purpose of the relatively large pressurized space comprising the space **27** and space within the cylinder **24** in communication therewith, as compared to the cyclic displacements of the piston **23**, is to assure that the value of the force present in the force-transmitting linkage defined by the air column connecting the casing structure and oscillator will remain substantially constant during each cyclic displacement of the oscillator so as to invest such force-transmitting linkage with the valuable incapacity to transmit vibration between two bodies necessarily interconnected thereby, being respectively an "unavoidably vibrating" body—namely, the oscillator **20**—and a body in which the occurrence of vibration is objectionable—namely, the oscillator cylinder and other elements of the composite casing structure.

A modified form of tool embodying the invention is illustrated in FIGURES 3 through 5, which both structurally and functionally is substantially the same as the tool heretofore described except that the oscillator and directly associated components have been divided into two separate but identical systems to effect an over-all compactness of the tool structure. Thus, instead of a single oscillator **20**, a plurality (namely, two oscillatory masses) are incorporated in the structure.

To facilitate appreciation of the correspondence of parts in the two tool structures, the same numerals are employed to identify such corresponding parts except that in the drawing illustrating the modified construction each of the reference numerals is in the 100 series. Thus, the tool has a handle-equipped casing **111** provided with a main cylinder **112** having a hammer **113** reciprocable therein for impact engagement with the upper surface **115***b* of an anvil **115** that engages the upper inner end of a spike **119** slidably held by the casing for limited axial movement with respect thereto. The hammer has and upper pressurizable surface **113***a* and a lower pressurizable surface **113***b*, and the axially projected areas thereof are substantially equal. The lower closure of the cylinder which sealingly surrounds the upper end portion of the anvil **115** is denoted with the numeral **112***a* and this surface, along with the surface **116***a* defining the lower end closure of the anvil chamber **116**, comprise the lower reaction surface of the tool. The cylinder also has an upper end closure (not shown) comprised mainly of the control valve that defines the upper reaction surface of the tool. The axially projected areas of the lower reaction surface and upper reaction surface are substantially equal, respectively, to the axially projected areas of the pressurizable hammer surfaces **113***b* and **113***a*.

Provided by the casing **111** are a pair of oscillator cylinders **121**, each of which has an oscillatory mass member **120** supported therein for reciprocable movement. Each oscillator has an upper pressurizable surface **120***d*, and corresponding thereto the upper end portion **121***c* of the associated oscillator cylinder has an end closure **121***a*. The aggregate surfaces **121***a* (one such surface being provided by each oscillator cylinder) comprise the upper counterbalancing surface of the tool structure, and the total or sum of the axially projected areas of these two surfaces—i.e., the area of the upper counterbalancing surface is substantially equal to the axially projected area of the lower reaction surface of the tool. Each of the oscillator cylinder spaces **121***c* is connected with the lower end portion of the main cylinder **112** through the passage network **117***b* and **117***a*. Each of the oscillatory masses **120** has a lower pressurizable surface **120***e*, and in facing relation therewith are the respective lower cylinder end closures **121***b*. The sum of the axially projected areas of the surfaces **121***b* which together comprise the lower counterbalancing surface of the tool structure is substantially equal to the axially projected area of the upper reaction surface of the tool. The lower end portion **121***d* of each oscillator cylinder is connected to the upper end portion of the main cylinder **112** through the respective passages **122**.

Corresponding to the structural components illustrated particularly in FIGURE 2 but inverted in orientation, each of the oscillators **120** is equipped with a downwardly extending stem **120***b* which carries a piston **123** adjacent the lower end thereof. The stem of each oscillator sealingly extends through the cylinder end closure **121**b associated therewith, and each of the pistons is reciprocable within a cylinder **124** therefor. The lower end portion of each cylinder **124** is exhausted to atmosphere through a plurality of ports **128**, and the upper end portion of each such cylinder is connected through a port and passage system **124***a* with a plurality of constant pressure spaces or chambers **127** defined by the casing parts **126** (FIGURE 5). Each of the pistons **123** reciprocates about exhaust or escape holes **125***a* which communicate directly with atmosphere, in contrast to the embodiment of FIGURES 1 and 2 wherein the corresponding holes **25***a* are connected with atmosphere through a collection chamber and spring biased valve. It will be understood that the constant pressure spaces **127** are connected to a source of compressed air through suitable passages and pressure reducing restrictions as in the prior embodiment—such source of compressed air being the actuating supply air delivered to the tool through the inlet coupling **110**.

It will be evident from the foregoing description of the tool structure illustrated in FIGURES 3 through 5 that the operation thereof is substantially the same as that of the tool embodiment shown in FIGURES 1 and 2. Therefore, the briefest operational summary will suffice, and it need only be said that the reactive force acting downwardly on the lower reaction surface and tending to vibrate the tool casing downwardly when the hammer is reciprocated upwardly through its return stroke is counterbalanced by the substantially equal and oppositely directed counterbalancing force resulting from the pressure forces in the oscillator cylinder spaces **121***c* acting upwardly on the upper counterbalancing surface of the tool

structure. Similarly, the upwardly directed pressure force reactively applied to the upper reaction surface of the casing when the hammer is reciprocated downwardly is counterbalanced by the oppositely directed pressure forces in the oscillator cylinder spaces 121*d* acting downwardly on the lower counterbalancing surface of the tool structure.

The composite automatic control system comprising the two control systems respectively associated with the two oscillators 120 maintains the same in positions of non-impacting intermediacy between the ends of their respectively associated cylinders 121, and the vibration-eliminating constant pressure columns respectively act downwardly upon the two pistons 123 and are regulatively adjusted in value to enforce such positional stability upon the oscillator as described in connection with the first embodiment of the invention. It may be noted that the reciprocatary axes of the oscillatory mass members 120 are coplanar with and symmetrically related to (in the illustrated structure, parallel to) the axis of reciprocation of the hammer 113, and, therefore, that the center of gravity of the total oscillator mass is coincident with that of the hammer so that no angular or torsional vibration is introduced into the tool by the reciprocatory motions of the oscillators.

The present invention constitutes a continuation-in-part of my copending patent application, Serial No. 742,878, filed June 18, 1958.

While in the foregoing specification embodiments of the invention have been described in considerable detail for purposes of making a complete disclosure, it will be apparent to those skilled in the art that numerous changes may be made in those details without departing from the principles or spirit of the invention.

I claim:

1. In a percussive tool, an outer casing structure, a first mass member reciprocable with respect to said outer casing structure, means linking said first mass member and said casing structure for the transmission of a reversing force therebetween energizing reciprocation of said first mass member relative to said casing structure for delivering impact force to a work element, a pair of mass members reciprocable with respect to said casing structure, means linking said pair of mass members and said casing structure for the transmission of a reversing force therebetween energizing reciprocation of said pair of mass members relative to said casing structure in force opposition to the reciprocatory movement of said first mass member, and a pair of means for respectively applying substantially constant forces to said pair of mass members in the direction of the motion of said first mass member as it initiates delivery of impact force to such work element.

2. The percussive tool of claim 1 in which each of said substantially constant forces is controlled by the respectively associated one of said pair of means to remain substantially constant during each reciprocatory cycle of said first mass member and additively to remain approximately equal to the average value of such impact force over any operating interval comprising a continuous sequence of such cycles.

3. In a percussive tool having a casing in which the occurrence of vibration is undesirable, a hammer reciprocable within said casing for the successive intermittent delivery of impact force to an impact-receiving-and-transmitting member, means for reciprocating said hammer by the application of forces alternately against the respective opposite ends thereof whereby reaction forces are alternately developed in opposite directions on said casing tending to vibrate the same, the force tending to reciprocate said hammer in a direction away from its impact relation with such impact-receiving member being in part impact reaction force developed thereagainst during the actual interval of impact, a pair of oscillators respectively reciprocable with respect to said casing generally along the reciprocatory axis of said hammer, means for reciprocating said oscillators in force opposition to the reciprocatory movement of said hammer whereby counter-active reaction forces are developed that oppose said reaction forces, said oscillators being dimensioned and arranged so that such counter-active reaction forces approximately equal said reaction forces tending to vibrate the casing, and a pair of means for supplementing the forces causing reciprocation of said oscillators by respectively applying thereto, generally in the direction of motion of said hammer immediately before the delivery of impact force thereby to such impact-receiving member, continuous forces operative between said casing and respective oscillators and which additively are substantially equal in average value to the average value of such impact reaction force intermittenly operative against said hammer.

4. The percussive tool of claim 3 in which a pair of automatic means are provided in respective association with said oscillators to enforce such equality between the average values of said continuous forces and such impact reaction force despite variations in the average value of the latter occurring in any continuous operating interval comprising a substantial number of impact cycles.

5. The percussive tool of claim 4 in which each of said means providing said continuous forces includes means for maintaining the values thereof substantially constant during the reciprocatory movement of said oscillators corresponding to any one reciprocatory cycle of said hammer.

6. The percussive tool of claim 3 in which said oscillators are located with the axes of reciprocation thereof substantially parallel and symmetrically oriented with respect to the axis of reciprocation of said hammer.

7. In combination with a percussive tool having a casing containing a hammer reciprocated with a non-constant frequency by application of a reversing force thereto which simultaneously tends to produce reactive casing vibration likewise of non-constant frequency, a pair of oscillatable elements, a support structure for said oscillatable elements, and means for developing a reversing force between said support structure and oscillatable elements for actuating the latter, said support structure tending to vibrate reactively during the oscillatory actuation of said oscillatable elements and being rigidly related with respect to said casing with the axes of movement of said oscillatable elements being coplanar and symmetrically related with respect to the axis of reciprocation of said hammer, said reversing force developed between said support structure and oscillatable elements being synchronized and quantified with respect to such reversing force reciprocating said hammer so as to effect a condition of anti-vibrative force counterbalance between said casing and said support structure.

8. In a percussive tool, a casing providing a cylinder having end closures respectively defining upper and lower reaction surfaces, a hammer reciprocable within said cylinder between said reaction surfaces, means for applying fluid pressure alternately between the respective ends of said hammer and the respectively opposing reaction surfaces to reciprocate said hammer, and a force-counterbalancing system comprising two pairs of opposed counterbalancing surfaces oriented in respective opposition to the aforesaid reaction surfaces, a pair of hermetic barriers respectively interposed between each pair of counterbalancing surfaces, and means for applying fluid pressure alternately against said respective pairs of counterbalancing surfaces substantially equal in value to and simultaneously with the fluid pressure application against the respective reaction surfaces opposed thereby, the area of each reaction surface and the aggregate area of the counterbalancing surfaces opposed thereby being approximately equal.

9. In a pneumatic percussive tool, a casing in which

the occurrence of vibration is objectionable and defining a first cylinder and a plurality of second cylinders, a plurality of free pistons respectively received within said cylinders for individual oscillatory motions relative thereto, pneumatic means applying accelerative forces to each of said free pistons and transmitting corresponding pneumatic reaction forces to said casing, the piston in said first cylinder being a blow-striking element and the other of said pistons being positionally controlled during the oscillatory movement thereof to prevent the transmission of impact force therefrom to said casing by suitable relative adjustment of the forces applied to said second pistons, and a plurality of pneumatic feedback means respectively responsive to positions assumed by said second pistons so positionally controlled to accomplish such adjustment, the algebraic sum of all of the positive and negative components of said pneumatic reaction forces along the axis of motion of said blow-striking piston remaining substantially constant during the typical oscillatory cycle thereof wherefore vibration of said casing along such axis is substantially eliminated.

10. The pneumatic percussive tool of claim 9 in which the axes of reciprocation of said second pistons are substantially parallel and are symmetrically oriented relative to the axis of reciprocation of said blow-striking piston and are parallel thereto.

11. The pneumatic percussive tool of claim 10 in which said second pistons comprise a pair thereof with their axes of reciprocation coplanar.

12. In a pneumatic percussive tool, a casing in which the occurrence of vibration is undesirable providing a main cylinder having end closures respectively defining upper and lower reaction surfaces, a hammer reciprocable within said main cylinder between said reaction surfaces, an impact-receiving-and-transmitting member slidably carried by said casing and extending upwardly into said main cylinder through and in sealing relation with a portion of the lower end closure thereof, means for applying fluid pressure alternately between the respective ends of said hammer and the respectively opposing reaction surfaces to reciprocate said hammer, a force-counterbalancing system comprising a pair of oscillator cylinders provided by said casing and each having end closures respectively defining upper and lower counterbalancing surfaces oriented in respective opposition to the aforesaid reaction surfaces, a pair of oscillators respectively reciprocable within said oscillator cylinders between the associated counterbalancing surfaces, first flow conduit means connecting the upper ends of said oscillator cylinders with the lower end of said main cylinder for simultaneously transferring pressures developed against said lower reaction surface to said upper counterbalancing surfaces, second flow conduit means connecting the lower ends of said oscillator cylinders with the upper end of said main cylinder for simultaneously transferring pressures developed against said upper reaction surface to said lower counterbalancing surfaces, the area of each of said reaction surfaces and the aggregate areas of the counterbalancing surfaces respectively opposed thereby being approximately equal, a pair of seal members respectively carried by said oscillators, a pair of pressurizable enclosures respectively receiving said seal members therein and each enclosure being provided with an inlet port adapted to communicate with a source of air under pressure and with an exhaust outlet port, means for establishing within each of said pressurizable enclosures a pneumatic column applying a force to the associated seal member, the volume of each of said enclosures being so related to the cyclic increases and decreases in the volume of the pneumatic column therein as produced by the cyclic reciprocations of the associated seal member and oscillator that substantially no change in pressure occurs within the enclosure because of such cyclic reciprocations, each of said seal members being adapted to traverse one of said ports associated therewith to maintain a selectively variable control over the rate of flow of air through the associated pressurizable enclosure for automatically adjusting the pressure therein to maintain said oscillators in a condition of impact-preventing separation with the counterbalancing surfaces respectively associated therewith.

13. The pneumatic percussive tool of claim 12 in which the axes of reciprocation of said oscillators are coplanar and symmetrical with respect to the axis of reciprocation of said hammer.

14. The pneumatic percussive tool of claim 13 in which said axes of reciprocation of said oscillators are parallel.

15. The pneumatic percussive tool of claim 12 in which each of said seal members is carried by the associated oscillator at the lower end thereof, and in which the associated pneumatic column applies a downwardly oriented force thereagainst.

References Cited in the file of this patent

UNITED STATES PATENTS

2,400,650	Leavell et al.	May 21, 1946
2,679,826	Leavell	June 1, 1954
2,730,073	Leavell	Jan. 10, 1956
2,748,750	Altschuler	June 5, 1956
2,752,889	Leavell	July 3, 1956
2,762,341	Solengro	Sept. 11, 1956