The present invention relates to improvements in internal vibrators and to a method of operating the same to carry out different kinds of construction work and the like by means of internal vibrations. Such work includes, for example, the boring of holes for poles and the like which may also be filled with concrete, the forming of lined or cased holes, the insertion of sheet piling or of hollowed or similar construction elements into the ground while the ground is at the same time compacted, as well as any other compacting work. According to the invention, all this work may be carried out in any kind of natural soil or in artificial fill by inserting a vibrator into the ground or fill and exerting vibrations therein upon the surrounding soil so as to tamp down such soil to consolidate the same.

The present invention particularly relates to a method of the above-mentioned type which concerns the application of an internal vibrator for acting upon the interior of the natural or artificial soil by exerting impacts thereon in a direction vertical to the vibrator axis, and in which the vibrator essentially consists of a closed housing which is suspended on one or more rods and contains a motor and a gyration mass which is driven thereby.

Internal vibrators have already been used for the above-mentioned purposes, for example, for compacting natural soil or artificial fill or for inserting pipes, hollow elements and the like into the ground for various purposes.

For work of this type it has previously been necessary while applying the vibrator also to supply water into the ground so as to soften the same and to change it into a semiliquid or pasty consistency so that, due to such change in the physical condition of the ground, the vibrator would sink into it and exert the desired lateral compacting effect thereon.

The applications of these prior methods were, however, limited to such types of soil or material which consisted of loose particles, particularly sand, which by application of liquids could be easily changed into a fluid condition.

It is therefore the principal object of the present invention to provide a method for also carrying out such work in any other type of natural or artificial soil or material which is suitable for being compacted by vibration, rolling, or tamping, for example, highly cohesive soil such as clay.

The present invention consists in the provision of an internal vibrator which consists of a housing containing the motor and the gyration mass, a non-vibrating or static weight member of the same diameter as the vibrator housing and above the housing, and a resilient coupling intermediate the housing and the weight member for preventing a transmission of the vibrations of the vibrator housing as such to the weight member. The invention further resides in the method of pressing such vibrator while in operation into the ground, and in placing and compacting the ground by the simultaneous action of the vibration and the static weight of the weight member. By interposing a resilient coupling between the vibrator and the weight member, the advantage is attained that the effective length of the vibrator as such, that is, of the housing containing the motor and the gyration mass, as well as the effective diameter of the vibrator may be made relatively small since the entire compacting force of the movements produced by the vibrator will be concentrated upon a very small area.

It is thus possible to attain a greater specific impact force than that which was previously attainable with vibrators of a known design and of a similar strength in which the vibrator and weight member were not separated by a resilient, vibration-absorbing coupling. According to the invention it is therefore also possible to displace and compact solid types of soil or other material. This is due to a large extent to the static weight of the weight member as provided according to the invention. Actual and extensive tests which have been carried out have shown that the penetration of the ground and the depth attainable by means of a vibrator according to the invention are practically unlimited.

The method and apparatus according to the present invention further permit pipes to be sunk into the ground without wasting a considerable part of the energy which should be utilized for the displacing and compacting work by transmitting the same to any upper pipes which are connected to the pipe actually to be sunk. Such transmission of vibratory energy may likewise be prevented by the provision of a resilient connection between the pipe actually to be sunk and those above it.

The ground which is displaced by the vibratory action and the static weight may also be replaced by filling in other materials, for example, a similar or different type of ground or concrete, or natural or artificial materials, such as bituminous mixtures which are especially adapted to be compressed. It is thus possible to increase the degree of compaction of bore holes or to form foundations which have especially solidified at certain points, such as enlarged pile shoes, or to build pier foundations which are produced by progressive compaction of the ground while the vibrator is gradually withdrawn. Additional materials of this kind or compressive agents may also be filled into the bore hole or be pressed into the surrounding ground during the upward or downward movement of the vibrator through feed pipes which are connected to the vibrator and preferably vibrate with the same. For example, a feed pipe which surrounds the vibrator may be formed with an open lower end which is releasably connectable with the vibrator. The feed pipe and the vibrator then form an annular chamber which may be filled with a suitable material. A portion of such material may be introduced into the bore hole merely by disconnecting the lower end of the feed pipe and by thereupon lifting the latter with respect to the vibrator. Subsequently, the feed pipe may be lowered, its lower end connected with the vibrator, and additional material introduced into the aforementioned annular space.

If the vibrator is used for compacting the ground particularly at certain points, it is advisable to displace the ground or the fill-in material by lifting and lowering the vibrator together with its weight member for a definite period of time until the vibrator will no longer penetrate under the action of its vibration and static weight of its weight member. This will then serve as a very simple means of insuring that the compaction at such place has been carried out to the highest possible degree. Especially for drilling work it is advisable to apply a vibrator housing with a conically pointed working head which is as
slender as possible, and to hold the same in a direction toward the ground so that the impacts of the vibrator will act against the area of the working head of the vibrator, the ground will be displaced primarily in the lateral direction, as this will insure an easy penetration into the ground.

If bore holes are to be formed in very cohesive, heavy soil such as heavy clay, it may occur that the vibrator will adhere to the ground by suction and be thereby prevented from lifting easily from the bottom of the hole and from continuing to operate properly. In order to avoid such suction and insure the proper operation of the vibrator even in such heavy soil, the invention further provides the working head of the vibrator with a relief valve which is adapted to open in the direction toward the bottom of the bore hole at the occurrence of any suction therein during the lifting stroke of the vibrator so that the area at the bottom of the bore hole around the working head will then be in communication with the outer atmosphere.

For carrying out the above-mentioned working methods, the present invention provides an apparatus which, as already indicated, essentially consists of a vibrator housing, preferably of a slender cylindrical shape, in which an electric motor is mounted which by means of a clutch is connected to a shaft carrying at least one unbalanced weight. This housing is closed at its end, for example, by means of a bolted-on cap with one or more apertures therein, which may serve as a passage for a cable leading from the motor to a source of electric current, as well as for other conduits for servicing and lubricating the motor and bearings, while the other end of the vibrator housing terminates in the shape of a pointed cone forming the working head of the vibrator. This working head may be of different shapes in accordance with the type of work to be carried out, and it may also be exchangeable, for example, by being screwed into the cylindrical vibrator housing.

The upper end of the vibrator housing is provided with a resilient coupling for connecting it to a weight member and for the purpose of preventing the vibrations from being transmitted from the vibrator itself to the weight member. This weight member may consist of one or more heavy suspension rods and/or of a pipe surrounding the suspension rod. It may also consist of a substantially cylindrical, thick-walled element of a certain length disposed above the elastic coupling and provided with internal bores through which the cable and other means are passed to the vibrator. The actual suspension rod is then secured to the free end of such weight member. Since the vibrator may also be suspended by means of one or more pipes, the inside of such pipe or pipes may also be filled with a suitable material to attain the required weight. However, regardless of whether the weight element consists of a suspension pipe, a rod, or a special weight member, it should not exceed the outer diameter of the vibrator. For the formation of bore holes, particularly if, at the same time pipes are to be inserted into the ground, it is especially advisable to use a vibrator, the eccentric action of which is directed vertically to the direction of feeding, and in which the connection between the vibrator and the weight member or suspension rod, as well as the connection between the covibrating pipe surrounding the vibrator and the upper pipe is made resilient so as to prevent the vibrations from being transmitted, on the one hand, from the vibrator to the weight member or upper suspension pipe, and on the other hand, from the covibrating pipe to the upper pipes which are connected thereto.

In some cases it has been found advisable to provide the conically pointed working head of the vibrator with an annular reinforcing bulge so that the increased diameter of the head at the periphery of this bulge corresponds either to the diameter of the vibrator or is of such a size as to be able to engage with and to take along a pipe which surrounds the vibrator. It is thus possible to prevent that the compaction of the ground which increases as the vibrator penetrates more deeply will reduce or prevent the lateral movability of the vibrator and thus reduce the impact force thereof. The maximum projection of the bulge should, however, not be larger than approximately one-half of the lateral sweep of the vibrator around the area of the bulge so that the inner wall of the bore hole will not collapse during the vibratory movements. It is further advisable to provide the working head of the vibrator with a plurality of ribs extending longitudinally thereof in a radially outward direction. These ribs are designed to prevent the vibrator from turning about its axis and to reinforce the head. For the use of the vibrator in a very cohesive soil the working head thereof is preferably made hollow and of a very resistant material such as steel, and the hollow space therein should be connected with the outer atmosphere through a conduit passing upwardly through the vibrator. Near its tip, the working head should then be provided with a relief valve which is adapted to open automatically toward the outside if a suction should occur between the bottom of the bore hole and the working head.

Further objects, features, and advantages of the present invention will appear from the following detailed description, particularly when read with reference to the accompanying drawings, in which-

Fig. 1 shows a side view, partly in section, of an apparatus for performing vibratory compacting operations according to the present invention;

Fig. 2 shows a side view, partly in section, of a modification of the apparatus according to Fig. 1;

Fig. 3 shows an end view of a vibrator head according to the invention; while

Fig. 4 shows an enlarged scale of a detail side view, partly in section of a modified working head of a vibrator according to the invention.

Referring to the drawings, and first particularly to Fig. 1, the housing 1 of the vibrator according to the invention is of cylindrical shape and consists, for example, of steel plate. A rotor 2 of an electric motor is rotatably mounted in bearings 3 and 4. A shaft 5 is connected to the shaft of rotor 2 by means of a clutch 5 and rotatably mounted in bearings 6 and 7. All of these bearings 3, 4, 6, and 7 are secured to housing 1 by suitable brackets. The unbalanced weights 9 consisting, for example, of flat rectangular cast-iron or forged elements are secured to shaft 8 by being welded or bolted thereto. The working head 10 of the vibrator housing 1 is of a conical shape. The upper conically reduced end of housing 1 carries a flange 11 which is secured thereto, for example, by welding, and supports a resilient coupling member 12. Coupling member 12 has two flange elements interconnected by a resilient portion, for instance of rubber, the lower flange element being secured to flange 11, for example, by bolts. The other flange element of coupling member 12 carries a threaded bushing 13 rigidly secured thereto which is screwed into the lower conical part of a weight member 14 of elongated cylindrical shape and the central bore of which is coaxial with and continues the central bore 15 in the weight member 14 which consists, for example, of steel. These bushings carry a cable 16 which connects member 2 to a source of electric current and serves as a ventilating channel and for containing conduits for a coolant and other means. The upper conical end of weight member 14 carries a screwed-in flange 17 on which a tubular suspension rod 18 is mounted. An outer tube 19, only the lower portion of which is shown in Fig. 1, is slipped over housing 1 and has a reduced lower end portion of suitable shape engaging resiliently into a grooved portion formed by an annular projection 20 on housing 1 so as to be mounted on the housing in an otherwise spaced relation thereto. This tube 19 may either serve as a protection for the vibrator, as a pipe to be left in the ground for lining the bore hole, or as
a means for passing any kind of additional material, for example, additional soil or concrete, into the bore hole. By the mentioned connection of tube 19 with the lower end of the vibrator housing 1, the vibratory movements of housing 1 will be transmitted to tube 19 so that the latter actually forms a peripheral extension of the vibrator. If tube 19 is made, for example, of steel plate and provided with an inner groove or an inner projection near its lower end, the lower end may be snapped into groove 20 of the tube 19. If the tube 19 is made, for example, of a resilient material, it will be separated from the vibrator housing for any other reason, it may again be disconnected therefrom by a blow upon its upper end.

Fig. 2 illustrates a modification of the vibrator according to Fig. 1, in which the housing, the electric motor including the bearings, the clutch, and the shaft carrying the unbalanced weights are designated by the same reference characters as in Fig. 1. The body of the vibrator is in this case connected by means of a resilient coupling 21 to a thick-walled pipe 22 which serves as a weight member. An upper extension tube 23 is slipped over the weight member 22 and connected to the lower tube 24 which corresponds to tube 19 in Fig. 1. Tubes 23 and 24 are connected by means of a resilient coupling which prevents the transmission of vibrations from tube 24 to tube 23 and any other extension tubes which might be utilized thereon. This resilient coupling consists of the two end portions 26 and 27 of tubes 24 and 23, respectively, which are fitted concentrically into each other and are provided with annular or helical grooves associated with each other and a resilient member 25 of rubber or the like or a series of separate rubber rings interposed between the end portions 26 and 27. The head 28 of the vibrator has a spherically conical working end, while the cylindrical upper portion thereof is again provided with an annular bulge 20 with which the lower reduced end of tube 24 engages.

Figs. 3 and 4 show enlarged detail views of the working end of the vibrator head 28, on which the outward bulge is designated with 29. Head 28 is further provided with a valve disk 30 which is adapted to fit tightly upon its seat by the action of a cylindrical spring 31. This seat in the wall of the vibrator head is milled and ground-in from the outside. The hollow head 28 communicates through a conduit 32 with the inside of housing 1 and further upwardly with the outer atmosphere. It is preferably provided with ribs 33 of triangular cross section extending from the pointed tip of head 28 radially upwardly along a certain length. These ribs which may also be of a different shape than illustrated in the drawings and may, for example, be of a wing-like shape are intended to prevent any undesired rotary movements of the vibrator.

The weight member may also be of a different design from that shown in Fig. 2 in which it forms a part of a tubular suspension rod. It may also form a tubular portion which surrounds a suspension rod of the usual type and be connected to the vibrator by a resilient coupling. However, the weight member may also be provided within a tubular suspension rod or it may be composed of several parts so that the weight thereof may be adjusted in accordance with the soil or material which is to be subjected to interior vibration.

Although my invention has been illustrated and described with reference to the preferred embodiments thereof, I wish to have it understood that it is in no way limited to the details of such embodiments, but is capable of numerous modifications within the scope of the appended claims.

Having thus fully disclosed my invention, what I claim is:

1. A method of internally compacting the ground, comprising the steps of forcing a vibrator downwardly into the ground to drill a borehole therein, exerting vibratory impacts in a lateral direction upon the wall of the borehole, the impacts being concentrated near the bottom of the borehole to simultaneously displace and compact the ground, surrounding said vibrator with a pipe having an open lower end, an annular channel being formed between the vibrator and the pipe, removably connecting the pipe near its lower end to the vibrator so that it vibrates with the vibrator and that its lower end is closed, feeding material into the upper end of said channel, disconnecting the pipe from the vibrator and lifting the pipe relative to the vibrator to open the lower end of the pipe and to discharge a portion of the material from said channel through the open lower end of the pipe into the borehole to be compacted therein.

2. An internal vibrator comprising a substantially cylindrical housing, a motor having a shaft mounted within said housing, a second shaft rotatably mounted within said housing, at least one unbalanced element mounted on said second shaft, a coupling connecting the motor shaft to the second shaft whereby rotation of the motor shaft produces lateral vibrations of the housing, a weight member of a diameter smaller than the diameter of the housing, a resilient coupling connected to one end of the housing and to the weight member, respectively, for absorbing the vibrations of the housing, a hollow head connected to the other end of the housing, a first passageway from the interior of the head to the interior of the housing, a second passageway from the interior of the housing through the weight member, a third passageway connecting the second passageway with the atmosphere, a fourth passageway between the interior and exterior of said head, and a relief valve in and normally closing said fourth passageway, said valve being adapted to be pressed outwardly by atmospheric air pressure reaching the valve through said first, second and third passageways to open said fourth passageway.

3. A method as defined in claim 1, further comprising the steps of lowering said pipe relative to the vibrator, thereupon connecting the pipe with the vibrator whereby to close the lower end of the pipe, and introducing additional material into said annular chamber.