March 16, 1937. C. VOORHIES 2,074,034

TAPPET CONSTRUCTION

Filed Nov. 14, 1934 2 Sheets-Sheet 1

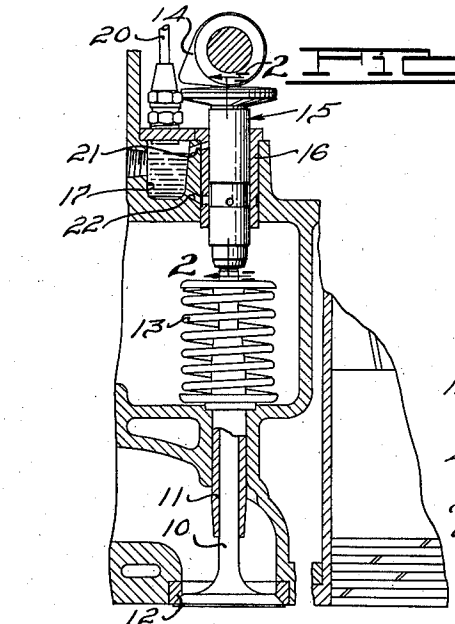


Fig. 1.

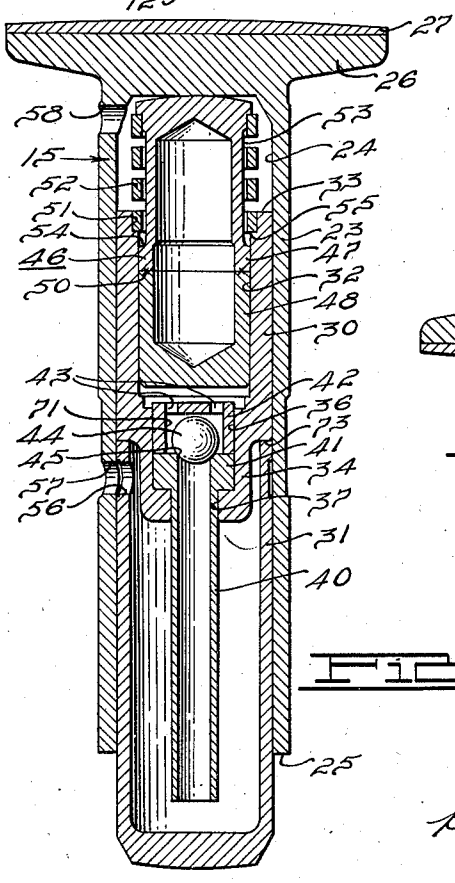


Fig. 2.

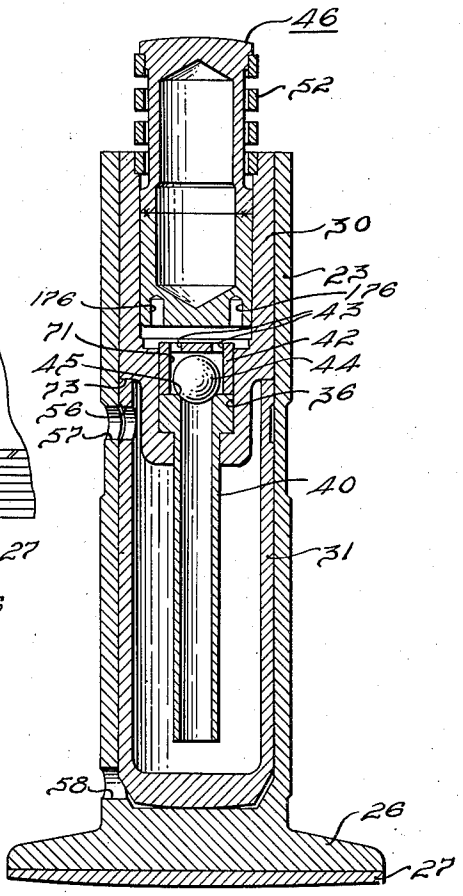


Fig. 3.

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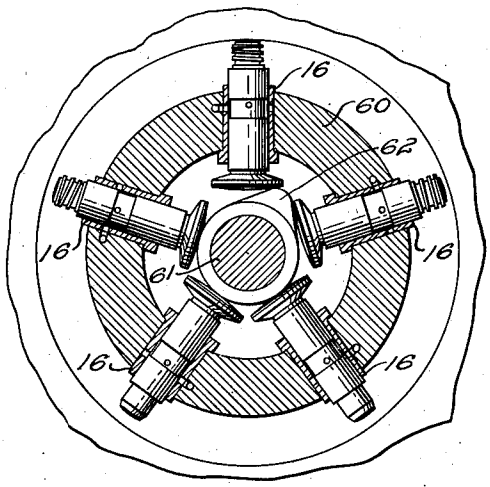


Fig. 4.

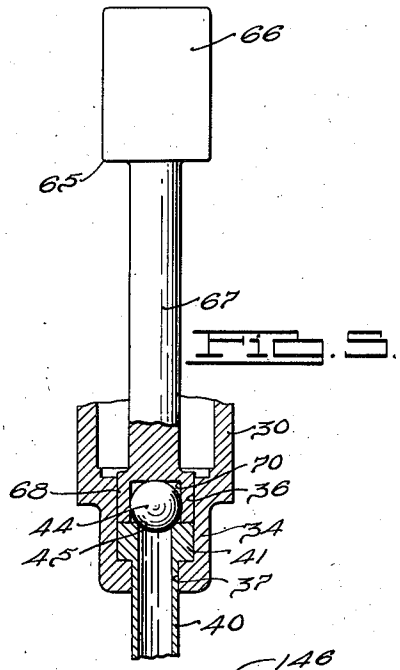


Fig. 5.

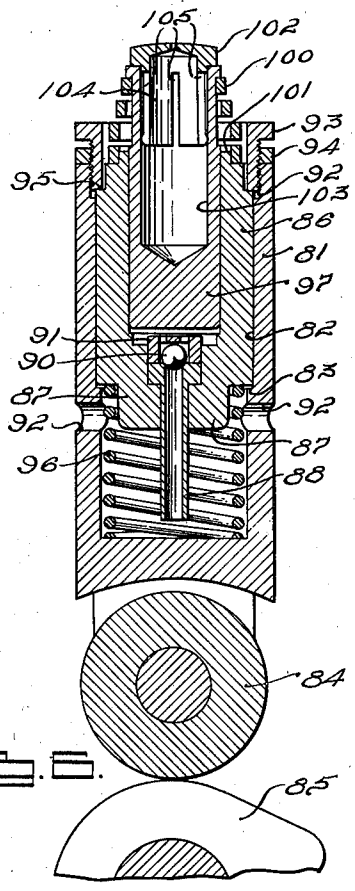


Fig. 6.

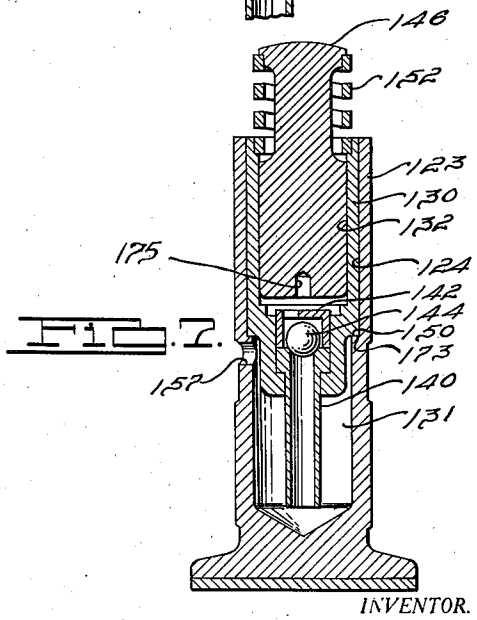


Fig. 7.

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TAPPET CONSTRUCTION

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Application November 14, 1934, Serial No. 752,902

23 Claims. (Cl. 123—90)

This invention relates to automatic compensating tappets for operating valves of internal combustion engines, and more especially to improvements in the construction and arrangement of compensating mechanism for tappets of such character.

The principal object of the invention is to improve the art of automatic compensating tappets especially adapted for operating moveable parts of internal combustion engines.

Another object is to provide an improved hydraulic tappet construction including a deep non-drain oil receptacle reversibly disposed within the tappet body, so that the tappet may be employed in upright, inverted, or any desired angular position.

A further object of the invention is to provide a novel arrangement of resilient means for urging the plunger of a hydraulic tappet construction outwardly against a valve stem, or the like, and to maintain a supply of liquid within the compression chamber for such plunger.

A further object is to provide novel means and method of seating a valve for controlling the trapping of liquid within such compression chamber, and for regulating the possible travel of such valve with respect to its seat.

Another object of the invention is to provide a compensating tappet construction including a separate element yieldably moveable with respect to the tappet body within adjustable limits for taking care of worn or otherwise out-of-true cam surfaces in conjunction with hydraulic compensating means operable with respect to such element for compensating for variations in length of certain moveable elements of an internal combustion engine, such variations being due to different operating conditions of the engine.

The type of tappet to which this invention relates comprises a tappet body provided with an enlarged cam engaging end, roller, or equivalent cam engaging means, and a tubular body which extends therefrom and contacts, or supports elements which contact, with the valve stem. Such tappet is usually provided with a bore which forms an oil reservoir or well for containing oil or other suitable hydraulic medium. It is usual practice also to fit a reciprocable plunger in the upper end of the bore, to provide a spring or other resilient means to urge the plunger outwardly out of the bore and against the value stem, and to provide a valve controlled compression chamber into which the oil or other liquid medium is introduced upon the outward movement of the plunger so as to provide a hydraulic column against which the end of the plunger will bear when it is forced downwardly into the tappet body.

In practical application of tappets, various problems have been encountered, one of which is the problem of providing adequate means for separating and bleeding air or compressible gas from the hydraulic medium carried in the reservoir of the tappet and of supplying substantially air-free and gas-free medium to the compression chamber so that the plunger will rest on as nearly as possible a hydraulic column which is substantially incompressible when the plunger is forced against the valve stem. Another problem has been to provide a tappet construction provided with such air separation means which can be installed in other than substantially vertical upright positions. Another problem has been to urge the plunger outwardly from the tappet body in such a manner that mechanical sticking of the plunger and tappet body will not occur, so that the plunger will not be cocked or misaligned so as to cause uneven wear of the same and of the bore in which it is received, and so that travel of the plunger will be restricted to desired limits. Other problems have been experienced in providing a valve for controlling the trapping of hydraulic medium in the compression chamber and in insuring that such a valve will not stick on its seat and will be restricted to the proper amount of travel with respect to such valve seat. Another problem has been to take care of worn out or otherwise out-of-true cam surfaces.

These problems have been solved by providing a tappet construction in which the parts contained within the tappet body may be reversibly arranged therein so that the tappet may be installed in vertically upright, inverted, horizontal, or in angularly disposed positions, or may be employed in rotary radial engines and still provide for the induction of solid or substantially incompressible medium into the compression chamber of the tappets. A novel arrangement of spring or resilient means has been provided which urges the plunger outwardly and at the same time prevents mechanical sticking, improper alignment of the plunger with respect to the tappet body, and limits plunger travel. A novel means and method for properly seating the compression chamber valve and for fixing the travel of such valve has also been provided. The tappet has also been provided with means for yieldably and adjustably compensating for incorrect cam surfaces, such as worn or

otherwise out-of-true surfaces of the valve operating cam.

Other objects, features and advantages will become apparent from the following description and appended claims.

For the purpose of illustrating the genus of the invention, various concrete embodiments are shown in the accompanying drawings, in which:

Figure 1 is a fragmentary, vertical section taken through an inverted valve and tappet arrangement of an internal combustion engine, said parts being shown in elevation;

Fig. 2 is an enlarged section taken on the line 2—2 of Figure 1.

Fig. 3 is a similar view of parts shown in Fig. 2 with the parts assembled for use in an upright vertical arrangement of valve tappets as they are more conventionally employed,

Fig. 4 is a more or less diagrammatic sectional view, certain parts being shown in elevation, of tappets arranged for operating valve of a stationary radial engine,

Fig. 5 is a similar view depicting a step in the assembling and seating of a compression chamber valve,

Fig. 6 is a vertical section taken through a hydraulic tappet, also provided with compensating means for taking care of worn or otherwise out-of-round surfaces of valve operating cams, and

Fig. 7 is a central vertical section taken through another form of hydraulic tappet and illustrates another way of compensating for worn or out-of-true surfaces of valve operating cams.

Referring to the drawings, and more especially to Figs. 1 and 2, numeral 10 indicates a valve reciprocably mounted within a valve guide 11, and adapted to be seated against a valve seat 12 by means of a valve spring 13. The valve 10 is adapted to be operated by a cam 14 through the intermediary of a tappet, indicated generally at 15. The tappet 15 is reciprocably mounted in a guide 16 arranged in axial alignment with respect to valve guide 11. A closed hydraulic chamber 17 may be provided adjacent the guide 16 for supplying liquid, usually oil from the lubricating system of the internal combustion engine to the tappet 15. An inlet conduit 20 is provided for conducting liquid from a suitable source of liquid under pressure to the chamber 17.

The conduit 20, in usual practice, supplies oil under pressure from the lubricating system of the internal combustion engine. The chamber 17 is so constructed as to provide air separation means by providing an air vent passage 21 extending from the top of the chamber 17 through the wall of this chamber and through the guide 16 to the clearance between the tappet 15 and the bore of the guide 16 at a point adjacent the top of such guide, and an outlet passage 22 leading from the bottom of the chamber 17 through the wall of said chamber and through the guide 16 for supplying the liquid, such as oil, to the interior of the tappet 15. The chamber 17 functions as a settling or air separation chamber allowing contained air or gases to float to the top of the liquid and to be vented from the chamber through the vent passage 21 and the clearance between the tappet 15 and guide 16 so that substantially gas-free and air-free liquid will be supplied from the bottom of the chamber 17 to the interior of the tappet. In this manner substantially incompressible liquid medium is supplied for operating compensating means contained within the tappet 15.

Reference may now be had to Fig. 2 which depicts more in detail the specific construction of the tappet 15. This tappet includes a cylindrical body portion 23 provided with a longitudinally extending bore 24 open at one end as indicated at 25 and closed at the opposite end by any desired form of cam-engaging means such as a mushroom-like cam engaging portion 26 provided with a hard metal wear piece 27. A separate cylinder 30 and an oil receptacle 31 are mounted for reciprocation within the bore 24 of the tappet body 23 and arranged in end-to-end relation. The separate cylinder 30 is provided with a longitudinal bore 32 open at its upper end 33 and partially closed at the lower end by means of a boss portion 34. The boss portion 34 is provided with two cylindrical recesses 36 and 37, the recess 37 being disposed at the outer extremity of the boss portion. A liquid conduit 40 provided with an enlarged head portion 41 is adapted to be press fitted within these recesses. The enlarged portion 41 occupies but a portion of the length of the cylindrical recess 36 and the main body of the conduit extends to a point adjacent to the closed bottom portion of the oil receptacle 31. A ball valve retainer 42 of cup-like form is press fitted into the remainder of the recess 36 in inverted position. The bottom wall of the valve retainer 42 is provided with apertures 43 for permitting the passage therethrough of oil or other suitable liquid medium. A ball valve 44 is disposed within the retainer 42 for limited movement therein and normally rests against a valve seat 45 provided at the upper end of the bore of the conduit means 40.

The plunger 46 is reciprocably mounted within the bore 32 of the separate cylinder 30 and is preferably made up of two pieces 47 and 48, centrally bored for lightness and welded together as indicated at 50. The plunger 46 is closed at the ends thereof and the outer end is slightly crowned for contact either with the inner surface of the cam engaging head 26 of the tappet body 23 in the arrangement illustrated in Figs. 1 and 2, or with the stem of a valve, such as 10 of Fig. 1, in the arrangement illustrated in Fig. 3 and later to be described.

The upper end 33 of the separate cylinder 30 is provided with a recess 51 opening inwardly toward the center of the bore 32 and outwardly of the open end of the separate cylinder. The lower end coil of a spring 52 is adapted to be received within the recess 51 and expanded therein so as frictionally to fix one end of the spring to the separate cylinder. The plunger 46 is provided with a peripheral recess extending from approximately the central portion thereof to a point adjacent the outer end of the plunger, a recess being made slightly more shallow adjacent the outer ends of the plunger for engagement with the upper end coil of the spring 52 which contracts thereon frictionally to fix the outer end of the plunger to the remaining end of the spring 52. By making the recess 53 deeper intermediate the portion engaging the outer end of the spring 52 and the central portion of the plunger, the spring will be free from interference or frictional engagement with the plunger except at the point of attachment therebetween. The spring 52 is fixed at one end to the plunger and at the opposite end to the separate cylinder so as to produce a slight oscillation between the

plunger and cylinder during its reciprocation so as to prevent mechanical sticking between the parts. The spring **52** is preferably made of rectangular sections having the longer dimensions of the sections of each coil extending longitudinally of the spring so as to weaken the same laterally and provide a spring which will not exert lateral forces upon the plunger so as to cause cocking or misalignment of the plunger with respect to the separate cylinder and produce uneven wear therebetween. The margin of the recess **53** arranged adjacent the longitudinal center of the plunger **46** provides a shoulder **54** cooperable with the lower end coil of the spring **52** to limit outward movement of the plunger with respect to the separate cylinder and thus prevent the plunger from lifting the valve to such an extent that it will hit the cylinder head of an internal combustion engine.

The provision of the recess **51** at the interior end surface of the separate cylinder **30**, aside from allowing the lower end coil of the spring **52** to be arranged therein so as to limit the outward movement of the plunger **46**, also affords protection of the upper marginal edge **55** of the bore **32** so that burrs or other irregularities will not be produced at this junction line in the event that the separate cylinder is dropped or hit by other objects prior to its assembly within the tappet. The separate cylinder **30** is provided primarily to facilitate the fitting of the plunger **48** within the separate cylinder **30** so that the desired leak-down rate between the cylinder and plunger will be obtained. To this end the separate cylinder is preferably made of a more machinable metal than that of which the tappet body is composed. The bore **32** and the peripheral surface of the plunger **46** may be formed within the proper mechanical limits and these surfaces made sufficiently smooth so that the desired leak-down rate between the plunger and the separate cylinder will be afforded. By providing the recess **51** at the interior end surface of the bore **32** instead of in an exterior surface of the separate cylinder, the end **33** of such separate cylinder more or less protects the marginal edge **55** of the bore **32** so that no burrs or other irregularities will be formed in such marginal edge to interfere with the fit of the plunger so as to undesirably affect the leak-down rate between the plunger and cylinder. After all the plungers and separate cylinders for an internal combustion engine have been properly surfaced within the desired mechanical limits the separate cylinders are filled to the desired level with a light liquid, such as kerosene, and the plungers, prior to having the springs **52** assembled thereon, are placed within the separate cylinders with weights of equal mass arranged upon the top surface of each of the plungers and the time of the descent of the plungers within the cylinders taken. Where marked differences between the time of the descent of the plungers within the cylinders occur, plungers are interchanged within the different cylinders until it has been ascertained that the leak-down rate for each of the plunger and cylinder assemblies is substantially constant. The springs **52** are then assembled with reference to the cylinder and plunger assemblies. The method of assembling the conduit means **40**, valves **44** and valve retainers **42** will be described more in detail with reference to Fig. 5.

Reference may now also be had to Fig. 3 which illustrates the oil receptacle **31**, separate cylinder **30** and plunger **46** assembled as a unit within the tappet body in the reverse direction from that indicated in Fig. 2. In order to reversibly arrange the oil receptacle, cylinder and plunger units within the tappet body, the length of each of these parts is so maintained that, with the plunger **46** in normal operating position, a port **56** through the wall of the oil receptacle will cooperate with a port **57** through a wall of the tappet so that the oil receptacle, cylinder and plunger are assembled in the position shown in Fig. 2, as well as that shown in Fig. 3. The ports **56** and **57** are accordingly arranged equi-distant from the end surface of the closed end of the oil receptacle and from the end surface of the closed end of the plunger **46** with the latter in normal operating position. An opening **58** is provided through the wall of the tappet body **23** adjacent to the head of cam engaging portion **26** to prevent trapping of air within the tappet body when the parts adapted to be contained therein are arranged as indicated in Fig. 2 or as indicated in Fig. 3.

The tappet assembled as shown in Fig. 2 is adapted to operate in conjunction with an overhead valve operating cam shaft as indicated in Fig. 1. The tappet assembly arranged as indicated in Fig. 3 is adapted to operate in conjunction with a cam operated shaft disposed below the valve tappet.

The valve tappet construction shown in Fig. 2 is adapted to operate either in vertical or inverted position using identical parts, the tappet assembled in either way being adapted to operate in either of the above indicated positions or in any angular position therebetween, including a horizontal position. This tappet construction is thus adapted for use in radial engines.

Referring to Fig. 4, an arrangement of tappets for a stationary radial engine is disclosed. In this construction a plurality of tappet guides **16** are mounted in a suitable support **60** with their axes extending radially from a cam shaft **61** and a plurality of tappets are disposed within these guides for operation by means of a cam **62** fixed to the shaft **61**. The three tappets arranged above the axis of the shaft **61** are assembled in the manner indicated in Fig. 3 and the lower two tappets are assembled as indicated in Fig. 2 so that the conduit means **40** will extend to points adjacent the bottoms of the oil receptacles **31**. It is to be understood, however, that one or more of the tappets assembled either in the manner shown in Fig. 2 or as indicated in Fig. 3 would operate if it were necessary to dispose them in a horizontal position. It is preferred, when feasible, to assemble the tappets **15** so that the conduit means **40** will extend downwardly in a substantially vertical direction so as to increase the effective vertical height of the oil receptacle **31** for the purpose of obtaining better separation of air from the oil supplied to the interior of the compensating mechanism of the tappets. In the case of rotary radial engines all the tappets would be assembled in the manner shown in Fig. 2 and in the two tappets disposed below the axis of the cam shaft **61** in Fig. 4, centrifugal motion of the tappets drawing the oil towards the closed ends of the oil receptacle **31** so that the lighter constituents or air contained therein will be forced toward the center of the tappets and bled or vented through the clearance provided between the separate cylinder and the tappet body and through the opening **58**.

It is also noted that the disposition of the tappets as indicated in Figs. 2, 3, and 4 prevents draining of the oil receptacles 31 during periods when the engine is idle.

Referring to Figs. 2 or 3 and 5, the method of assembling a conduit 40, a valve 44, and a valve retainer 42 will be here described. As previously indicated, the conduit means 40 make a drive or press fit within the boss portion 34 of the separate cylinder 30 with sufficient tightness to maintain the conduit means in place and to prevent material leakage of oil between the tappet cylinder and the conduit means. A tool 65, illustrated in Fig. 5, comprises a head portion 66, a stem 67 and a work engaging means 68, the latter being in the form of an inverted cylindrical cup portion adapted to fit the recess 36 so as to be guided thereby with the recess 70 therein adapted similarly to fit the ball valve 44. The end of the work engaging portion is disposed adjacent the upper surface of the enlarged portion 41 of conduit means 40 and the tool 65 employed to drive or press the conduit means 40 into position. The ball 44 is disposed within the cylindrical recess 70 of the work engaging means 68, the recess 70 being of sufficient depth so that the ball will press a valve seat 45 into the head portion 41 of conduit means 40. The width of the valve seat 45 is made sufficient so that the ball valve 44 will effectively seal the upper end of the bore of conduit means 40. A wide valve seat would have a tendency to cause sticking of the ball valve and interfere with the operation of the hydraulic compensating means. The definite depth of the cylindrical recess 70 of the tool 65 also enables the ball valve to be given the desired travel with respect to the valve seat 45. The means for restricting the travel of the ball valve with respect to the valve seat 45 is preferably in the form of the valve retainer 42 perforated at the bottom surface thereof as indicated at 43 in Figs. 2 and 3, the cylindrical interior recess 71 of the retainer 42 being of a slightly larger diameter than that of the recess 70 of the tool 65 so as more loosely to receive the ball valve. The depth of the recess 71 is slightly greater than the depth of the recess 70 of the work engaging portion 68 of tool 65 so that the ball valve is permitted a slight amount of travel away from the seat 45. The depth of the recess 71 is made of a definite predetermined value so that as the retainer 42 is pressed into the recess 36 to abut the head portion 41, the ball valve 44 will be restricted to the desired amount of travel.

In the operation of the present construction, as the cam 14 or 62 rotates with the tappet head 26 contacting the dwell portion of the cam, the tappet body 23 moves toward the axis of the cam shaft under the influence of the valve spring, such as 13 of Fig. 1. Normally, in a rigid and non-expansible type of tappet, the pressure of the valve stem against the end of the tappet would cease shortly before the tappet reaches the dwell portion of the cam, thus relieving substantially all the pressure of the valve upon the tappet. In the present construction, however, when the pressure of the valve stem ceases, the coil spring 52 will urge the plunger 46 outwardly and maintain its contact with either the valve stem or the head portions 26 of a tappet body 23. The outward movement of the plunger 46 will reduce the pressure in the space between the end of the plunger 46 and the bottom of the separate cylinder 30 and permit the ball valve 44 to raise from its seat 45, under the relatively greater pressure in the oil receptacle 31, and permit oil from the receptacle 31 to flow past the ball valve 44 and fill the space between the end of the plunger 46 and the bottom of the separate cylinder 30. This space is ordinarily termed the compression chamber of the tappet. As the tappet body is moved away from the axis of the cam shaft by rotation of the cam, the ball valve will either be on its seat or soon will be pressed on to its seat to close off the compression chamber within the tappet and trap the oil then contained therein, thus providing a substantially incompressible hydraulic column which will maintain the plunger 46 in firm contact with the valve stem 10 or with the head portion 26 of the tappet body so as to force the closed end of the oil receptacle 31 into firm contact with the valve stem 10 on cam engaging head of the tappet body. In the arrangements shown in Figs. 1 and 2, either the closed end of the oil receptacle or the closed outer end of the plunger 46 will be maintained in firm contact with the valve stem 10 during the entire stroke of the tappet. The pressure of the plunger 46 against the trapped oil in the compression chamber normally may cause a slight leakage of oil around the edges of the plunger, the leakage thus obtained being determined by the leak-down rate between the plunger and the bore 32 of the separate cylinder 30. The oil so eliminated will be replaced as the cycle of operation repeats and the pressure of the valve stem upon the plunger is relieved when the tappet rides upon the dwell portion of the cam and permits the spring 52 to force the plunger 46 outwardly, thus permitting the ball valve 44 to raise from its seat and admit more oil into the compression chamber between the end of the plunger 46 and the bottom of the separate cylinder 30, as previously described.

It is essential that the hydraulic column beneath the plunger 46 be as incompressible and as rigid as possible when oil is trapped in the compression chamber in order to permit accurate and dependable adjustment and timing of the valve operation. Some air or gas will inevitably be contained in the oil which is pumped into the oil receptacle 31 of the tappet and this air or contained gas will rise to the top of the oil receptacle. This contained air or gas will leak or be bled from between the end surface of the open end of the oil receptacle 31 and the shoulder 73 provided adjacent the boss portion 34 of the tappet cylinder and thence through the clearance provided between the separate cylinder and the tappet body.

When the tappets are arranged in vertically disposed positions as indicated in Figs. 1 to 3, inclusive, or the upper tappet of Fig 4 it is noted that the full vertical heights of practically the whole of the oil receptable 31, i. e., the distance from the open end thereof to the bottom of the conduit means 40 is available for air separation within the oil receptacle. With the tappet disposed in inclined position as indicated by the four remaining tappets of Fig. 4, the effective vertical heights for air separation from the oil within the oil receptacle will be reduced, however, it is noted that even with the tappets of the present construction arranged in horizontal positions that the distance from the end of the tappet means body to the bore of the oil receptacle 31 is sufficient to effect

separation of air or gases of the oil contained within the receptacle 81. The tappet has been found to operate satisfactorily in a horizontal position.

Reference may now be had to Fig. 6 in which a modified form of tappet is disclosed in which in addition to means in the form of hydraulic compensating mechanism employed to compensate for difference in length of parts of the valve operating means due to expansion and contraction of certain parts thereof, caused by different operating conditions of the engine, further means is provided for compensating for worn or out-of-true surfaces of the valve operating cam. In this construction a valve tappet body 81 is provided with a stepped bore 82 so as to afford a shoulder 83, facing the open end of the tappet body. The lower end of the tappet body is closed and provided with suitable cam engaging means, which may be in the form of a roller 84 adapted to engage a cam 85. A separate cylinder 86 is disposed in the larger diametered portion of the said bore 82, the lower end of the cylinder shouldering against the annular shoulder 83 to restrict or limit the depth to which the separate cylinder may be projected within the bore 82. The smaller diametered portion of the bore 82 serves as an oil receptacle for the hydraulic compensating mechanism. The lower end of the separate cylinder 86 is partially closed by a boss portion 87 which serves as a mounting for the conduit means 88, corresponding to the conduit means 40 of the previously described embodiment. A ball valve 90 and a valve retainer 91 corresponding to the valve 44 and retainer 42 of the previously described embodiments are mounted within the boss portion 87 in practically the same manner as above described. Oil or other suitable liquid, under pressure, is admitted through ports 92 to the interior of the oil receptacle portion of the stepped bore 82. An adjustable limiting means is also provided for restricting the outward movement of the separate cylinder 86 with reference to the tappet body 81. The tappet body 81 is provided with a recess 92 in the interior surface and adjacent the open end thereof which is internally threaded for the reception of an externally threaded adjustment sleeve 93. A lock nut 94 is also threaded on the exterior surface of the adjustment sleeve 93 to lock the latter in the desired position with respect to the tappet body 81. The separate cylinder 86 is recessed radially inwardly adjacent the upper marginal edge thereof to provide a shoulder 95 adapted to abut the lower end of the adjustment sleeve 93. A spring 96 is enclosed within the oil receptacle portion of the stepped bore of the tappet body in compressed condition between the closed end of the tappet body at the lower end of the separate cylinder. The spring normally biases the separate cylinder 86 against the inner end or the adjusting sleeve 93. A plunger 97 is disposed for reciprocation within the bore of the separate cylinder 86, these parts being formed within the desired mechanical limits to provide the desired leak-down rate between the plunger and the separate cylinder. A spring 100 frictionally engages a shoulder portion 101 at the upper end of the separate cylinder 86 and at the opposite end similarly engages the plunger 97 adjacent its upper end to yieldably urge the plunger 97 outwardly with respect to the separate cylinder. When the cam roller 84 rides on the dwell portion of the cam 85, the spring 100 will urge the plunger 97 outwardly to reduce the pressure within the compression chamber located between the lower end of the plunger 97 and the bottom of the separate cylinder 86 so as to draw hydraulic medium within the compression chamber. As the cam lifts the tappet, the ball valve 90 will close the passage through the conduit means 88, trapping the hydraulic medium within the compression chamber and providing a substantially solid hydraulic column below the plunger 97.

The hydraulic compensating mechanism of this tappet construction is adapted to compensate for inequalities in the length of operating parts of the valve actuating mechanism due to expansion and contraction of the parts during various operating conditions of an internal combustion engine. When the cam 85 presents a worn or out-of-true surface the adjustment sleeve 93 may be backed outwardly of the tappet body 81 to allow a slight reciprocation of the tappet body 81 with reference to the separate cylinder 86. The spring 96 yields to compensate for the out-of-true surface of the cam 85. If the surface of the cam 85 is not out-of-true the adjustment sleeve 93 may be threaded inwardly of the tappet body until the separate cylinder 86 is locked against movement with respect to the tappet body. As wear of the cam occurs or the surface of the cam is found to be out-of-true, the adjustment sleeve 93 may be backed outwardly of the tappet body by an amount equal to the amount by which the surface of the cam 85 is out-of-true. This prevents the tappet mechanism from maintaining the valve off its seat and prevents noise in the operation of the valve.

A self-aligning cap 102 may be provided at the upper end of the plunger 97. The plunger 97 is provided with a recess 103 extending longitudinally thereof for the reception of a resilient sleeve portion 104 provided by cutting a plurality of slots longitudinally of such sleeve portion as indicated at 105. The position of the slots 105 provides resilient portions which makes the cap self-aligning with respect to squaring up the face of the flange with the end of the plunger and also allows the sleeve portion to be self-fitting within the bore in the plunger without requiring that these parts be made within close mechanical limits.

Reference may now be had to Fig. 7 which illustrates a modified form of tappet adapted to provide a definite amount of compressibility of the tappet for the purpose of compensating for worn or out-of-true working surfaces of the operating cam for the tappet. In this construction, the tappet body 123 is provided with a stepped bore 124 forming a shoulder 150 which is adapted to abut the shoulder 173 on the lower end of a separate cylinder 130 to limit the inward movement of the separate cylinder with respect to the tappet body. No separate oil receptacle is provided in this construction, however, the lower portion of the stepped bore 124 provides an oil receptacle 131 within the lower end of the tappet body 123. A solid plunger 146 is reciprocably mounted within the bore 132 of the separate cylinder 130 and is adapted to be biased outwardly with respect to the separate cylinder by means of a spring 152 constructed and arranged to correspond with the spring 52 of the construction shown in Figs. 2 and 3. The separate cylinder 130, tubular conduit means 140, ball valve means 144 and ball valve retainer

142 are constructed and arranged to function in the same manner as the corresponding elements 30, 40, 44, and 42 of the construction shown in Figs. 2 and 3. A port 157, corresponding to the port 57 of the first described embodiment, is provided for admitting liquid under pressure to the tappet body to supply liquid medium for the compensating mechanism arranged therein. In this embodiment, instead of providing for resiliently opposed movement of the separate cylinder with respect to the tappet body as illustrated in Fig. 6, the hydraulic medium of the compression chamber is rendered slightly compressible so as resiliently to oppose inward relative movement of the piston with respect to the separate cylinder.

A small bore 175 leads upwardly from the inner end of the plunger 146 to provide a chamber of a predetermined volume for trapping air or other compressible medium therein, which compressible medium is adapted to yield in response to increases of pressure of the liquid medium contained within the compression chamber of the tappet. Since the boring 175 opens downwardly, a definite amount of compressible medium, such as air or compressible gas from the liquid medium utilized in the compensating mechanism of the tappet, will be trapped within the bore. The remainder of the air or gas contained within the liquid medium will be bled or vented through the clearance provided between the plunger 146 and the bore 132 of the separate cylinder 130. The compressible medium contained within the boring 175 will provide the tappet with a definite amount of compressibility for the purpose of compensating for worn or otherwise out-of-true working surfaces of the operating cam for the tappet. The size of the boring may be varied to provide the desired amount of compressibility of the tappet for compensating purposes.

Referring back to Fig. 3 of the drawings, it is noted that essentially the same expedient may be employed in the reversible tappet construction shown in Fig. 3 by providing borings 176 in the lower end of the plunger 46. In the case of hollow plunger, such as shown in Fig. 3, it is preferred to employ a plurality of borings arranged other than coincident with the axis of the plunger so that the borings may be made at points affording sufficient depth of metal for such borings without puncturing the lower end closure of the plunger. These borings contain the proper quantity of air or other compressible medium to provide a definite amount of compressibility of the tappet to compensate for worn or otherwise out-of-true working surfaces of the operating cam. The size and number of borings 176 may be varied to suit the needs of a particular valve cam.

As many changes could be made in the above constructions and many apparently widely different embodiments of this invention could be had without departing from the spirit thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What I claim is:

1. In a valve tappet, the combination with a tappet body provided with a longitudinal bore closed at one end and open at the other, of hydraulic compensating mechanism including an oil receptacle and reversibly receivable in said bore so that the receptacle can be disposed in substantially upright position for both substantially upright and substantially inverted positions of the tappet body.

2. In a valve tappet, the combination with a tappet body provided with a longitudinal bore closed at one end and open at the other, of hydraulic compensating mechanism including an oil receptacle and a separate cylinder both reciprocably received in said bore, a valve control passage adjacent one end of said cylinder, conduit means communicating at one end with said passage and at its other end with the interior of said receptacle at a point adjacent the bottom of said oil receptacle, and means for admitting oil to said receptacle, said hydraulic compensating mechanism being reversibly receivable in said tappet body, whereby said mechanism may be arranged so that the other end of the conduit dips into oil in said receptacle for all positions of said tappet body.

3. A hydraulic valve tappet comprising a tubular tappet body closed at one end, a tubular oil receptacle reciprocably received in said tappet body and closed at one end, a tubular cylinder reciprocably received in said tappet body and provided with a valve controlled passage adjacent one end thereof, the remaining ends of said tappet body, oil receptacle, and cylinder being open, and a plunger reciprocably received in said cylinder, said oil receptacle and separate cylinder being assembled in end to end relation in the bore of said tappet body with the open end of said receptacle abutting that end of said separate cylinder which includes the valve controlled passage and said tubular body being adapted reversibly to receive said cylinder, plunger and oil receptacle assembly.

4. In a valve tappet, the combination with a tappet body provided with a longitudinal bore closed at one end and open at the other, of hydraulic compensating mechanism including an oil receptacle and a separate cylinder both reciprocably received in said bore, a valve controlled passage adjacent one end of said cylinder, said oil receptacle being provided with an open and a closed end, said cylinder being provided with a shoulder adjacent said valve controlled passage, the open end of said oil receptacle being arranged in abutting relation against said shoulder, a plunger reciprocably received in said cylinder with one end of the plunger extending outwardly therefrom, conduit means communicating at one end with said passage and at its other end with the interior of said oil receptacle adjacent the closed end of the latter, both said tappet body and said oil receptacle being provided with ports through the walls thereof and adapted to register both when the hydraulic compensating mechanism is assembled with the closed end of the oil receptacle abutting the closed end of the tappet body, and when the mechanism is assembled with the outwardly projecting end of the plunger abutting the closed end of the tappet body.

5. In a valve tappet, hydraulic compensating mechanism including a longitudinally reciprocable plunger, a cylinder for said plunger and provided with an open end, and a coil spring extending between the open end of said cylinder and the outer end of said plunger, an end coil of said spring contracting inwardly and frictionally engaging an outer surface of said plunger, and the opposite end coil of said spring expanding outwardly and frictionally engaging an inner surface of said cylinder, said plunger

being provided with a shoulder engageable with said last-named end coil of said spring to limit outward movement of said plunger with respect to said cylinder.

6. In a valve tappet, hydraulic compensating means including a longitudinally reciprocable plunger, a cylinder for said plunger and provided with an open end, a recess in said cylinder opening into the bore of said cylinder and outwardly of the open end thereof, and a coil spring having an end disposed in said recess and expanding outwardly frictionally to engage the side wall of said recess, said plunger being recessed intermediate its ends and on the outer periphery thereof to provide opposed shoulders thereon, the end coil at the opposite end of said spring engaging one of said shoulders and contracting inwardly frictionally to engage said plunger, the remaining shoulder on said plunger being engageable with the expanding coil of said spring to limit outward movement of the plunger with respect to said cylinder.

7. In a valve tappet, hydraulic compensating mechanism including a longitudinally reciprocable plunger, a cylinder for said plunger and provided with an axially concentric boss portion at one end thereof, said boss portion being provided with two axially concentric cylindrical recesses therein of different diameters, the smaller diametered recess being arranged at the outer end of the boss portion, a tubular element projecting longitudinally through said boss and outwardly of said cylinder and provided with a radially outwardly enlarged and cylindrical portion at one end adapted to make a press fit in a portion of the larger diametered recess in said boss portion, said enlarged end of the tubular element being provided with a narrow valve seat at the end of the bore of said element, a ball valve arranged in said larger diametered recess of said boss portion, and a cup shaped ball retainer disposed in inverted position in said larger diameter recess and making a press fit therein, said retainer being provided with passages through the bottom portion thereof and arranged to limit travel of said ball with respect to said valve seat.

8. In a valve tappet, the combination with a tappet body provided with a longitudinal bore closed at one end and open at the other, hydraulic compensating mechanism including a separate cylinder reciprocally received in said bore, said cylinder being provided with a pair of endwise directed shoulders arranged one adjacent each end thereof, said tappet body being provided with a shoulder arranged to engage one of the shoulders on said cylinder to limit inward movement of the cylinder in said bore, an adjusting sleeve threaded to the tappet body adjacent the open end of said bore and engageable with the other shoulder on said cylinder for adjustably limiting outward movement of the cylinder in said bore, and resilient means for urging said cylinder outwardly of said tappet body.

9. In a valve tappet, the combination with a tappet body provided with a longitudinal bore closed at one end and open at the other, hydraulic compensating mechanism including a separate cylinder reciprocably received in said bore, said cylinder being provided with a pair of endwise directed shoulders arranged one adjacent each end thereof, said tappet body being provided with a shoulder arranged to engage one of the shoulders on said cylinder to limit inward movement of the cylinder in said bore, and an adjustable nut threaded to the tappet body adjacent the open end of said bore and engageable with the other shoulder on said cylinder for adjustably limiting outward movement of the cylinder in said bore, resilient means for urging said cylinder outwardly of said tappet body, and means for admitting liquid under pressure to the tappet body to supply liquid medium for said compensating mechanism and also for urging said cylinder outwardly of said tappet body.

10. The combination with a valve operating cam, of a tappet comprising a tappet body, a separate cylinder reciprocally mounted in said body, means for limiting movement of said cylinder in said tappet body towards said operating cam, adjustable means for limiting movement of said cylinder in said tappet body away from said cam, resilient means for urging the cylinder away from said cam, and towards said adjustable limiting means, and hydraulic compensating mechanism including a plunger reciprocably mounted in said cylinder and means for admitting and trapping liquid medium between said plunger and said cylinder.

11. In a valve tappet, the combination with a tappet body provided with a longitudinal bore closed at one end and open at the other, hydraulic compensating mechanism including a separate cylinder reciprocably mounted in said bore, of endwise directed shoulders arranged one at each end of said separate cylinder, a fixed shoulder on said tappet body for limiting movement of the cylinder within said bore towards the closed end thereof, adjustable means carried by said tappet body adjacent the open end of said bore for adjustably limiting movement of said cylinder in the direction of the open end of said bore, and a coil spring arranged in said bore between the closed ends thereof and the inner end of said cylinder for urging the cylinder towards said adjustable limiting means.

12. The combination with a valve operating cam, of a tappet comprising a tappet body, hydraulic compensating mechanism including a plunger, reciprocally mounted in said tappet body, spring means for biasing said plunger outwardly with respect to said tappet body, and valve means for admitting and trapping liquid medium within the tappet body so as to extend said plunger outwardly relative to the tappet body, and other means for biasing said plunger outwardly relative to said tappet body and yieldable to compensate for out-of-true working surfaces of said valve operating cam.

13. The combination with a valve operating cam, of a tappet comprising a tappet body, a separate cylinder in said tappet body, hydraulic compensating mechanism including a plunger reciprocably mounted in said cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, and valve means for admitting and trapping liquid medium between said plunger and said cylinder, and other compensating means for biasing said plunger outwardly relative to said tappet body and yieldable to compensate for out-of-true working surfaces of said valve operating cam.

14. In a hydraulic valve tappet, the combination with a tappet body provided with a bore substantially closed at one end and open at the other, of hydraulic compensating mechanism including a separate cylinder, an oil receptacle, a plunger reciprocable in said separate cylinder,

and a spring for expanding said plunger and separate cylinder assembly, said compensating mechanism being reciprocably and reversibly receivable in the bore of said tappet body.

15. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at one end, a separate cylinder disposed in said bore, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, said separate cylinder making a slidable fit in the bore of said tappet body for venting gas from the bore of the tappet body through the clearance between said separate cylinder and the tappet body.

16. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at one end, a separate cylinder disposed in said bore, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, and a tubular portion of reduced diameter on one end of said separate cylinder, and projecting downwardly into the bore of said tappet body, said separate cylinder making a slidable fit in the bore of said tappet body.

17. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at its lower end, a separate cylinder disposed in the upper part of said bore, the lower part of said body including a liquid reservoir, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, and a tubular portion of reduced diameter on the lower end of said separate cylinder and projecting into the reservoir in the lower part of the tappet body, said separate cylinder making a slidable fit in the bore of the tappet body for venting gas from said reservoir at a point above the lower end of said tubular portion.

18. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at one end, a separate cylinder disposed in said bore, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, and a tubular portion of reduced diameter on one end of said separate cylinder and projecting downwardly into the bore of said tappet body, said separate cylinder being free of surface grooves and passages in the wall portions thereof and making a slidable fit in the bore of said tappet body for venting gas from such bore at a point above the lower end of said downwardly projecting tubular portion.

19. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at its lower end, a separate cylinder disposed in the upper part of said bore, the lower part of said body including a liquid reservoir, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, and a tubular portion of reduced diameter on the lower end of the separate cylinder and projecting into the reservoir in the lower part of the tappet body, said separate cylinder being free of passages or grooves in the wall portion thereof and making a slidable fit in the bore of the tappet body for venting gas from said reservoir at a point above the lower end of said tubular portion.

20. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at one end, a separate cylinder composed of a more machinable metal than that composing said tappet body and disposed in said bore, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, and a tubular portion of reduced diameter on one end of said separate cylinder and projecting downwardly into the bore of said tappet body, said separate cylinder making a slidable fit in the bore of said tappet body for venting gas from said bore at a point above the lower end of said downwardly projecting tubular portion.

21. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at its lower end, a separate cylinder composed of a more machinable metal than that composing said tappet body and disposed in the upper part of said bore, the lower part of said body including a liquid reservoir, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, and a tubular portion of reduced diameter on the lower end of the separate cylinder and projecting into the reservoir in the lower part of said body, said separate cylinder making a slidable fit in said bore for venting gas from said reservoir at a point above the lower end of said tubular portion.

22. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at its lower end, a separate cylinder disposed in said bore, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, said separate cylinder being provided with an axially bored boss portion at the lower end thereof, a suction tube press fitted into the bore of said boss portion and projecting downwardly into the bottom portion of the bore in said tappet body, said separate cylinder making a slidable fit in the bore of said tappet body for venting gas from the bore of the tappet body at a point above the lower end of said suction tube.

23. In a hydraulic valve tappet, a tappet body having a longitudinal bore closed at its lower end, a separate cylinder disposed in the upper part of said bore, the lower part of said body including a liquid reservoir, a plunger in said separate cylinder, spring means for biasing said plunger outwardly with respect to said separate cylinder, said separate cylinder being provided with an axially bored boss portion at the lower end thereof, a suction tube and a valve cage press fitted into the bore of said boss portion, said suction tube projecting downwardly into the bottom portion of said reservoir, said separate cylinder being free of passages, or grooves in the wall portions thereof and making a slidable fit in the bore of the tappet body for venting gas from said reservoir at a point above the lower end of said suction tube.

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