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Bosch

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[54] **HYDRAULIC CONTROL APPARATUS FOR A HYDRAULIC MACHINE**

[75] Inventor: **Paul Bosch,** Ludwigsburg, Germany

[73] Assignee: **Robert Bosch GmbH,** Stuttgart, Germany

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[52] **U.S. Cl.** .... **180/66 R,** 180/77 R, 60/19, 60/443, 60/445, 60/451, 60/452

[51] **Int. Cl.** **B60k 17/10**

[58] **Field of Search** .... 60/19, 52 VS, 53 R, 60/443, 445, 451, 452; 180/66 R

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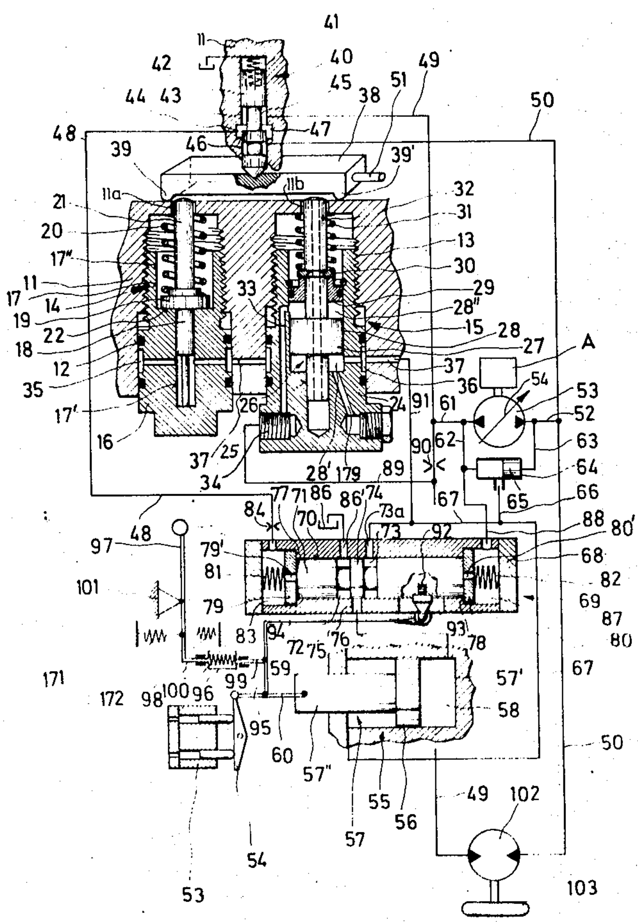
Primary Examiner—Edgar W. Geoghegan
Attorney—Michael S. Striker

[57] **ABSTRACT**

A control apparatus for an adjustable hydraulic machine includes a power amplifier for adjusting the hydraulic machine under the control of a control valve generally set by manual setting means. Limiting units are selectively and detachably attached to supporting means, and respond to excessive fluid pressure, flow, or torque, to influence a limiting valve which controls the flow to the control valve so that the power amplifier operates the adjusting means of the hydraulic machine to reduce the pumped amount of fluid so that normal operating conditions are automatically obtained. One or several limiting units can be attached and connected into the hydraulic circuit of the machine, and independently control the limiting valve.

21 Claims, 7 Drawing Figures



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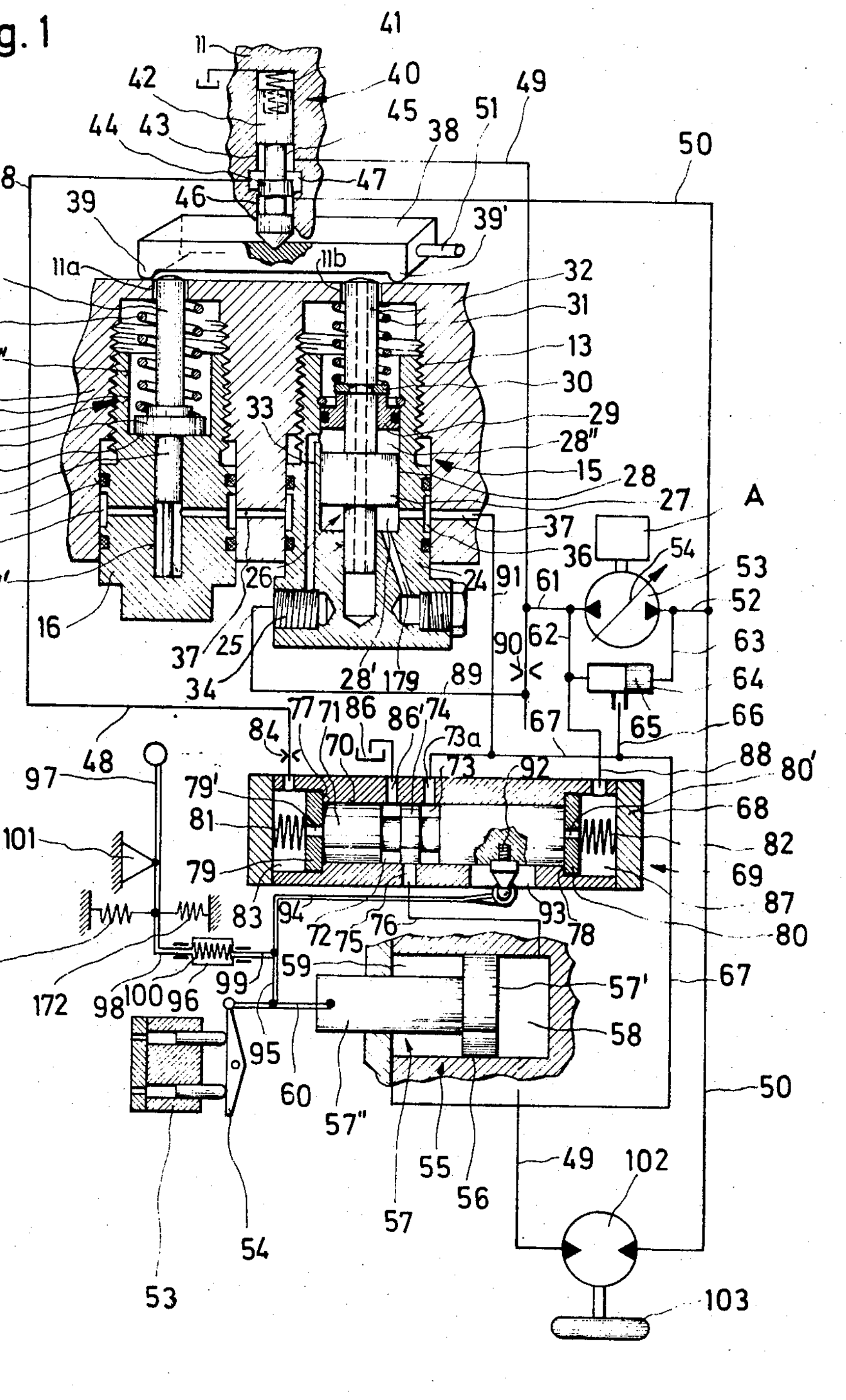
3 Sheets-Sheet 1

Fig. 1



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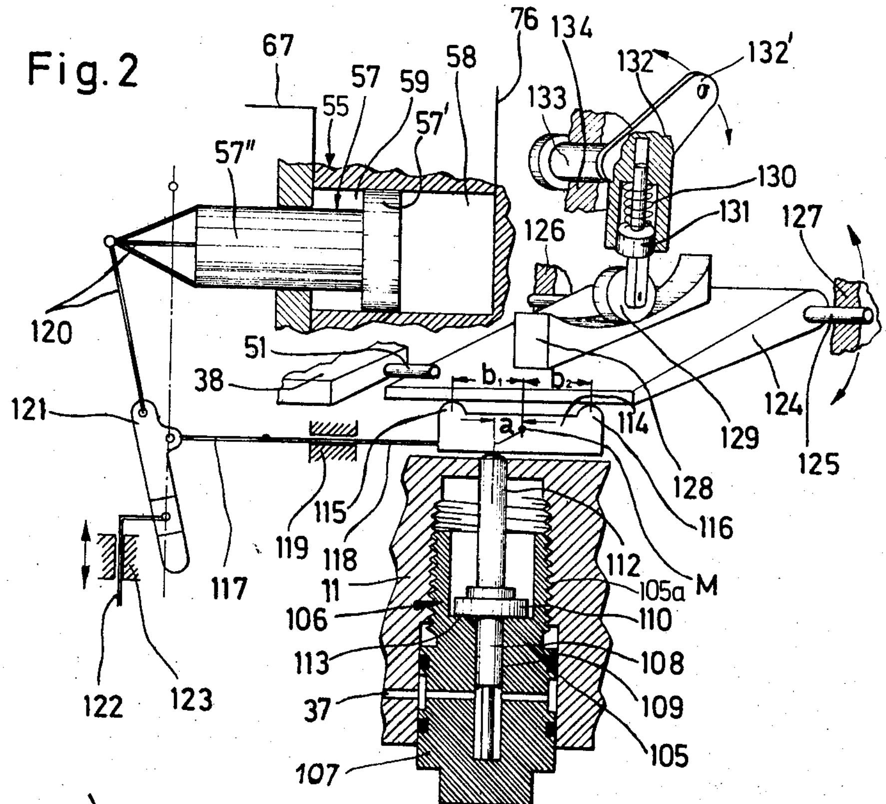


Fig. 2

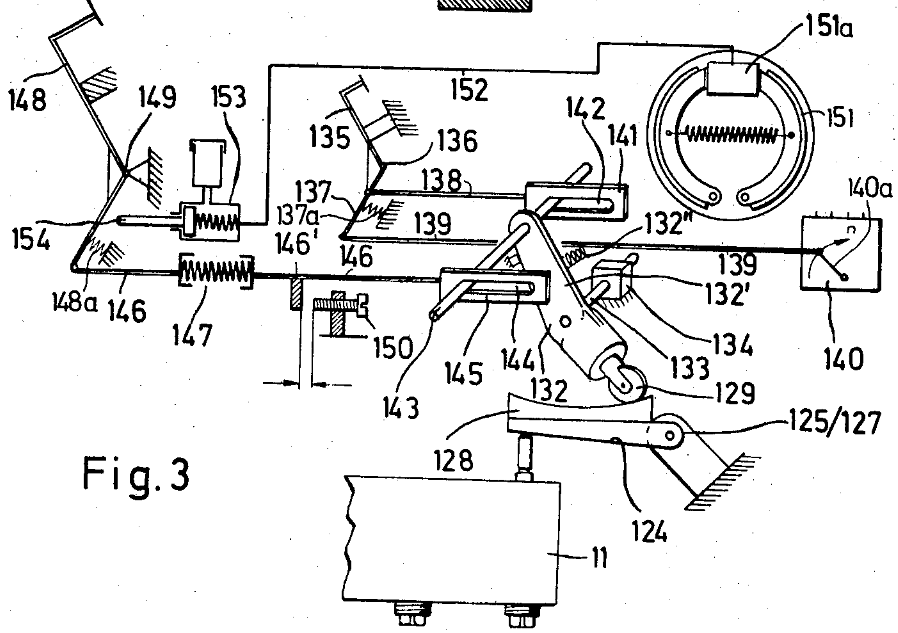


Fig. 3

Fig.4

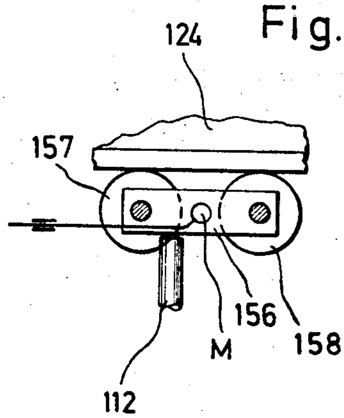


Fig5a

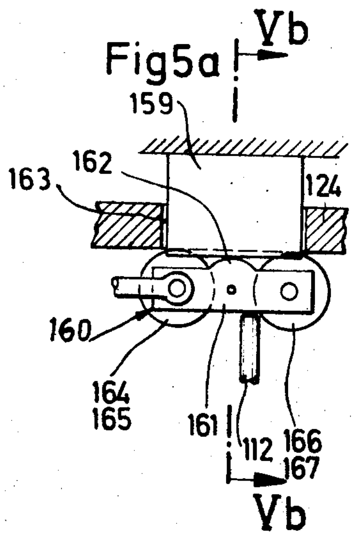
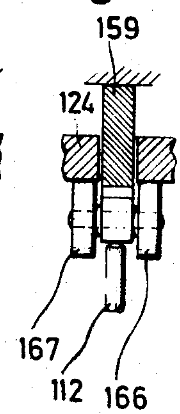


Fig.5b



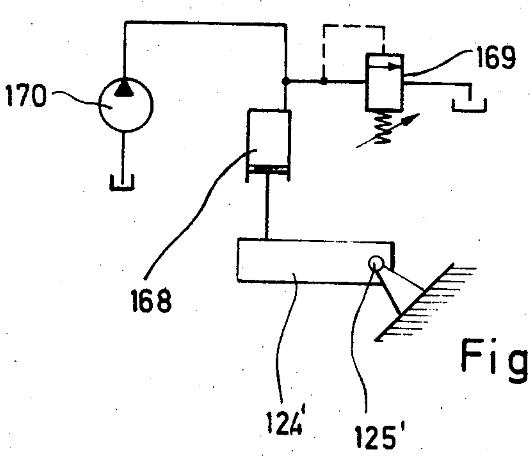


Fig.6

HYDRAULIC CONTROL APPARATUS FOR A HYDRAULIC MACHINE

BACKGROUND OF THE INVENTION

The present invention relates to a hydraulic control and regulating apparatus for a hydraulic machine, which may be a pump or hydraulic motor, which has a pressure responsive power amplifier whose position is controlled by a control valve so that the power amplifier sets the adjusting means of the hydraulic machine, following the position set by manually operated setting means.

The German Pat. 1,528,382 discloses a control apparatus of this type which is provided with a lever on which the force of a biassing spring and of a control piston act in response to the pressure in the hydraulic system, and which determines the position of the piston of a power amplifier which adjusts the stroke of the hydraulic machine, such as an axial piston pump. The apparats of the prior art is capable of obtaining the follow-up control, a regulation of the torque, and a limiting of the pressure of the machine. However, the apparatus has the disadvantage that only a single control or regulating operation can be carried out in a particular position of the biassing means.

SUMMARY OF THE INVENTION

It is one object of the invention to overcome the disadvantages of prior art apparatus, and to provide a control apparatus for an adjustable hydraulic machine which permits a great number of control and regulating functions which may take place simultaneously, or independently of each other.

With these objects in view, the present invention provides limiting units which can be selectively mounted on supporting means of the hydraulic machine or control apparatus, and which respectively controls a limiting valve, irrespective of whether one or several limiting units are used. The limiting valve influences the control valve to operate the power amplifier to correct the position of the adjusting means of the hydraulic machine to reduce the flow volume for reducing the excessive flow conditions to which one or several limiting units have responded. The setting means include a manually operated member connected with the valve slide of the control valve for adjusting the position of the same when a follow-up control by the power amplifier is being carried out.

The arrangement of the invention permits it to use one or several limiting units, singly or in combination, in accordance with the flow condition or conditions which are to be corrected. It is advantageous to construct the limiting units with bodies having threads for being threaded into threaded bores of attaching portions of the supporting means. For example, three attaching portions with threaded bores may be provided, and limiting units for limiting flow pressure, flow volume or amount, and torque can be threaded into the threaded bores, if desired, but it is also possible to use any one of the limiting units alone, or different combinations of two limiting units, which can be easily exchanged and replaced, which is advantageous also for repairs.

If the hydraulic machine operates as a pump, the pressure and torque limiting units can operate with the fluid pumped in forward or reverse direction, but these limiting units are also fully effective when the hydraulic machine is used as a hydraulic motor. However, the flow amount limiting unit is only operative in one flow direction, which has been found sufficient for practical use.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is partly a sectional view, and partly a schematic diagram illustrating a control apparatus according to the present invention applied to a hydrostatic transmission including a pump and a hydraulic motor driving wheels of a car supporting the hydrostatic transmission and a combustion engine driving the pump of the transmission, the control apparatus being shown with a pressure limiting unit and with a flow limiting unit;

FIG. **2** is partly a sectional view, and partly a schematic view, illustrating another part of the apparatus shown in FIG. **1** comprising a torque limiting unit;

FIG. **3** is a schematic view illustrating a torque limiting unit controlled from a brake pedal and a gas pedal of a combustion engine driving the hydraulic machine;

FIG. **4** is a fragmentary elevation illustrating a modified part of the apparatus shown in FIG. **2**;

FIG. **5***a* is an elevation, and FIG. **5***b* is a front view taken on line *b*, *b* in FIG. **5***a*, and being a front view, partly in section of the device shown in FIG. **5***a;* and

FIG. **6** is a schematic view illustrating another modification of the apparatus shown in FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A housing **11**, only partly shown in FIG. **1**, has two parallel stepped bores **12**, **13**, partly provided with thread, in which a pressure limiting unit **14** and a flow limiting unit **15** are located.

The pressure limiting unit **14** includes a cartridge body which is tightly threaded into the stepped bore **12**, and has a stepped blind bore **17** in whose lower portion **17'**, a measuring piston **18** is tightly guided. Piston **18** has a central flange **19** on which the lower end of a spring **20** abuts whose upper end abuts a shoulder formed by the bore **11***a* in supporting means **12**. Meausring piston **18** includes a pressure pin **21** which in the position of rest of the pressure limiting unit **14** projects through bore **11***a*. In this position, flange **19** abuts shoulder **22** formed by the bore portions **17'** and **17''**. The spring **20** can be pretensioned by threading the body **16** more or less deeply into the stepped bore **12**.

The flow limiting unit **15** includes a cartridge body **24** tightly screwed into the stepped bore **13**, and having a stepped bore **25** in which a stepped measuring piston **26** is slidingly guided. A piston portion **27** divides a space **28** into a lower pressure chamber **28'** and an upper pressure chamber **28''** which is bounded by a fixed partitioning plate **29** on which the flange **30** of the stepped piston **26** abuts in a position of rest due to the action of a spring **31** abutting flange **30** and having an upper end supported on an annular shoulder formed in supporting means 12 by the bore 11*b*. A pressure pin portion 32 of the stepped piston 26 projects through opening 11*b*. A channel 33 connects pressure chamber 28'' with a connector bore 34 in body 24 to which a pipe can be attached, as schematically indicated by the line 89. The force of spring 31 can be adjusted by screwing the body 24 more or less deeply into the stepped bore 13.

Body 16, as well as body 24, is provided on the outer surface with an annular groove 35 and 36, respectively, with which a channel 37 in the supporting means 12 communicates. Channel 37 is continued by flow line 91, as schematically shown. The height of each annular groove 35, 36 is substantially greater than the diameter of the channel 37.

Above the supporting means or housing 11, a transmitting plate 38 is located, as schematically illustrated in a perspective view in FIG. 1. The rectangular plate 38 has lateral portions projecting beyond the bore portions 11a and 11*b* of the stepped bores 17, 26 and has marginal fulcrum bulges 39 and 39', respectively, which rest on the top face of the supporting means 11, permitting tilting of plate 38.

A limiting valve 40 is located above the tiltable plate 38, and has a slide 42 which is guided in a blind cylinder bore 43 of a portion of the supporting means 11. Slide 42 has two axially spaced annular grooves 45, 46 which are separated by a piston portion 44. The cylinder bore 43 has an annular groove 47 into which a conduit 48 opens. A conduit 49 opens in the cylinder bore 43 above the piston portion 44, and another line 50 opens below piston portion 44. Tiltable plate 38 has an axially projecting pin 51 at one lateral end.

Conduit 50 is connected by branch conduit 52 with an adjustable and reversible pump 53, for example an axial piston pump, whose adjusting means 54 can be operated by means of a power amplifier 55 which includes a differential piston 57 having a larger piston portion 57', dividing the cylinder 56 into two chambers 58 and 59, and a smaller piston portion 57'' which projects out of cylinder 56. Piston portion 57'' is mechanically connected by a link 60 with the adjusting means 54 of the pump 53. As shown in the left lower corner of FIG. 1, the adjusting means 54 is a double-armed lever cooperating with two pistons located in two cylinder bores of a part of pump 53. Pump 53 and the adjusting means 54 are also shown in a schematic illustration on the right side of FIG. 1 where pump 53 is shown to be driven by a prime mover which may be a combustion engine A.

Conduit 49 is also connected with pump 53 by branch conduit 61. The two branch conduits 52 and 61 are connected by conduits 62 and 63, respectively, with a reversing valve 64 which includes a reversing piston 65 which is shiftable between two end positions for connecting branch conduits 62, 63, respectively, with a conduit 66 which opens into a conduit 67. One end of conduit 67 opens into the pressure chamber 59 of cylinder 56 of the power amplifier 55, while the other end of conduit 67 communicates with a port 73*a* in the housing or valve body 68 of a control valve means 69.

Valve body 68 has a longitudinal cylinder bore 70 in which a control slide 71 is slidingly guided. Control slide 71 has two annular grooves 72, 73 separated by a piston flange 74 whose axial width is slightly greater than the diameter of a bore or port 75 in valve body 68. A schematically shown conduit 76 opens into port 75, and connects the cylinder bore 70 with the pressure chamber 58 of cylinder 56 of power amplifier 55.

The cylinder bore 70 of control valve 69 has two annular shoulders 77, 78 which are spaced a distance equal to the axial length of control slide 71. Each shoulder 77, 78 is engaged by a disk 79 and 80, respectively, on which springs 81 and 82 abut which are supported by the end walls of the valve body 68. In the position of rest, springs 81 and 82 center control slide 71 by means of disks 79, 80. Each disk 71, 80 has a central bore 79', 80'. A conduit 48, with a throttle 84, connects the chamber in which spring 81 is located with the annular groove 47 in the limiting valve 40.

As noted above, conduit 67 which extends to the chamber 59 of the power amplifier 55, opens into a port 73*a* in valve body 68 located on the right side of piston flange 74 when control slide 71 is in the illustrated position of rest determined by springs 81 and 82. On the left of flange piston 74, a port 86' is located, which is connected with a discharge reservoir 86. The space 87 in the valve body 68 is connected by a conduit 88 with one end of the cylinder of the reversing valve 64.

Conduit 49 is connected by conduit 89 with the connector bore 34 in the cartridge body 24 of the flow limiting unit 15. A throttle 90 is provided in conduit 49 between the connecting point of conduits 89, 49, and the connecting point of conduits 61, 49. Conduit 67 is connected by a conduit 91 with channel 37 in supporting housing means 11. Conrol slide 71 carries a fixedly secured pivot means which projects out of a slot 93 in valve body 68 of control valve 69. A connecting link 94 is pivotally connected with pivot means 92 at one end, and with a double armed lever 95 at the other end. The free end of lever 95 is articulated to link 60 which connects power amplifier piston 57 with the adjusting means 94 of pump 93.

Substantially in the middle of lever 95, a resilient linkage 98 is articulated, which is connected with a manually operated setting lever 97. The resilient linkage 96 includes two cranked rods 98, 99 which are yieldingly connected by a spring 100. Setting lever 97 is mounted for angular movement in a bearing 101 which is supported by stationary supporting means.

A conduit 50 connects the limiting valve 40 with a hydraulic motor 102 which drives wheel means 103. Conduit 49 also connects limiting valve 40 with the hydraulic motor 102, but is shown partly broken off for the sake of clarity of the illustration.

In the illustrated arrangement pump 53 and hydraulic motor 102 together constitute a hydrostatic transmission with a closed fluid circuit by which the wheels 103 of a vehicle are driven.

The delivered fluid volume of pump 53, and thereby the speed of the wheels 103 and of the vehicle, is set by setting lever 97. If the piston 42 of the limiting valve 40 is in the illustrated lower position, the two spaces 83 and 87 of the control valve 69 are connected by conduits 48, 49, 61, 62 and 88. Consequently, no one sided pressure acts on control slide 71 which can be shifted by means of setting lever 97, and linkage means 94, 95, 92 to any desired position for controlling the flow into and out of the pressure chamber 58 of the power amplifier 55 which operates the adjusting means 54 of pump 53 for adjusting the delivered fluid volume and direction of flow of fluid in pump 53.

The flow of pressure fluid for controlling the differential piston 57 of the power amplifier 55 is as follows:

It is assumed that the setting lever 97 is turned out of its neutral position in counter clockwise direction as viewed in FIG. 1 while the pump 53 discharges into conduits 61, 49. Pressure fluid also flows through branch conduit 62 to the reversing valve 64 which permits flow through conduits 66, 67 into the pressure chamber 59 of the powr amplifier 55, and also into the annular groove 73 in the control slide 71 of control valve 69.

If control slide 71 is shifted to the right against the action of spring 82, pressure fluid from pressure chamber 58 of the power amplifier 55 flows through conduit 76 and annular groove 72 to the reservoir 86. The pressure in pressure chamber 59 shifts the differential piston 57 also to the right as viewed in FIG. 1, so that the delivered fluid volume of the pump 53 is increased so that the vehicle moves fast or slow depending on the angular displacement of setting lever 97.

If setting lever 97 is turned back in clockwise direction, as viewed in FIG. 1, high pressure fluid from conduit 67 and annular groove 73 in control slide 71 enters conduit 76 and pressure chamber 58 of power amplifier 55 so that the same pressure prevails in chambers 58 and 59. Since the effective piston surface in pressure chamber 58 is substantially greater than the annular effective piston surface bonding pressure chamber 59, the differential piston 57 is shifted to the left as viewed in FIG. 1, so that the delivered fluid volume of pump 53 is reduced by displacement of the adjusting means 54. Pressure fluid transported by pump 53 through conduit 49 to hydraulic motor 102, flows through the hydraulic motor 102 and conduit 50 back to pump 53. It is, of course, possible to provide an auxiliary pump for producing the required pressure before pump 53 is fully operative.

If setting lever 97 is turned out of the neutral position in clockwise direction, conduit 50 becomes the high pressure conduit, and reversing valve 64 connects branch conduit 63 with conduit 66. The operations of the control valve 69, power amplifier 55, and adjusting means 54 take place as described above, but the wheels 103 turn rearward, and the direction of movement of the vehicle is reversed.

The above-described operations effect a follow-up control for adjusting the pump by means of a power amplifier or booster in accordance with the setting of setting lever 97.

If the discharge pressure of pump 53 rises above a predetermined maximum limit, which is determined by adjusting the spring 20 of the pressure limiting unit 14, measuring piston 18 is moved upward against the action of spring 20. The pressure required for the displacement of the measuring piston 18 is supplied from pump 53 to the pressure limiting unit 14 through conduit 62, reversing valve 64, conduits 66, 67, 91, conduit 37 in supporting means 11, and annular groove 35 into the end portion 17′ of the stepped bore 17. Pressure pin 21 of measuring piston 18 raises the left end of the tiltable plate 38 which turns about the marginal fulcrum bulge 39′ in clockwise direction, so that the limiting piston 42 of the limiting valve 40 is raised against the action of spring 41 so that piston portion 44 of limiting piston 42 interrupts the connection between conduit 48 and conduit 49, and then connects, during further upward movement, the high pressure conduit 48 with the low pressure conduit 50 so that pressure fluid flows out of chamber 83 of control valve 69 to the low pressure side of the pump. The high pressure prevailing in chamber 87 of control valve 69 displaces control slide 71 against the action of spring 81 to the left, as viewed in FIG. 1, so that conduits 67 and 76 are connected by the annular groove 73 on the control slide 71. Pressure fluid can now flow, as described above, into the pressure chamber 58 of the power amplifier 55, and a differential piston 57 adjusts the pump 103 to deliver a smaller amount of fluid, as required by the prevailing excess pressure. This operation is only possible since the mechanical linkage connecting the differential piston 57 of the power amplifier 55 with the setting lever 97, includes the resilient linkage 96. Due to the resilient yielding of linkage 96, setting lever 97 can remain in its set position. When the pressure drops again to the permissible maximum limit, the tiltable plate 98 is urged by spring 41 of the limit valve 40 and by limiting piston 42 back to the normal position in which both fulcrum bulges 39, 39′ abut the top face of the supporting means 11. Consequently, limiting piston 42 assumes again the illustrated position in which the spaces 82, 83 in the control valve 69 are connected with each other so that the differential piston 57 of the power amplifier 55 returns to the position corresponding to the previously manually selected position of setting lever 97.

If the flow of fluid out of the pump is reversed by adjustment of the adjusting means 54 of pump 53, the pressure limiting unit operates in a corresponding manner, since in the reverse condition of pump 103, conduit 50 is the high pressure conduit, and conduit 49 is low pressure conduit, the raising of the left end of the tiltable plate 38, and the corresponding movement of limiting piston 42 effects a shifting of the control slide 71 of control valve 69 in the opposite direction than before takes place. When control slide 71 moves to the right as viewed in FIG. 1, the pressure chamber 58 of power amplifier 55 discharges into reservoir 86, and differential piston 57 also moves to the right, operating the adjusting means 54 to adjust the pump to a reduced output volume.

If the hydrostatic transmission 53, 102 is used for driving a vehicle, and in the event that the same moves downward on a slope due to the action of gravity, hydraulic motor 102 is operated as a pump, and pump 53 is operated as a hydraulic motor. If in this operational condition, the pressure of the fluid rises above the maximum limit to which the pressure limiting unit 14 is set, pump 53 is adjusted to a greater delivery of fluid so that the transmission ratio of the hydrostatic transmission is reduced. In this manner, the pressure limiting unit 14 is effective under all operating conditions.

If the delivered volume of pump 53 becomes too great and exceeds a maximum limit, flow limiting unit 15 becomes effective to reduce the pumped volume. However, flow limiting unit 15 is effective only in one flow direction of pump 53, in contrast to the pressure limiting unit 14. The function of the flow limiting unit 15 is as follows:

The throttle 90 in conduit 49 is an important element in the limiting of the flow. Throttle 90 produces a pressure differential, and the pressure upstream of throttle 90, in conduit 61 acts in pressure chamber 28′ of the cartridge body 16, since it is transmitted through branch conduit 62, reversing valve 64, conduit 66, 67, 91 and channel 37 into pressure chamber 28′.

The lower pressure downstream of throttle **90** is effective in pressure chamber **28''** and is transmitted by the fluid in conduit **89** and channel **33**. The opposite effective faces of the stepped limiting piston **26** are of equal size. When the delivered fluid volume of pump **53** exceeds the maximum limit determined by adjustment of spring **31**, and if the pressure differential at the throttle **90** is sufficiently great, the stepped measuring piston **26** moves upward, and its pressure pin **32** engages transmitting plate **38** and tilts the same about the marginal fulcrum bulge **39** in counterclockwise direction so that the limiting piston **42** of the limit valve **40** is raised. due to the upward displacement of the limiting piston **42** of the limiting valve **40** the fluid volume delivered by the pump is again reduced, as described above. The setting lever **97** remains in its previously set position when the differential piston **57** of power amplifier **55** acts on the adjusting means **54**, since the resilient linkage **96** yields without displacing setting lever **97**. The maximum limit of the pumped flow can be varied by screwing the cartridge body **24** of the flow limiting unit **15** more or less deeply into the threaded portion of the stepped bore **13**, which varies the pretension of spring **31**.

The operations described above correspond to a follow-up control with setting of a desired delivered fluid volume, with limiting of the pressure and of the flow volume.

The above-described hydraulic control circuit can be provided with a torque regulating and limiting unit **106** in addition to any one of the limiting units **14** and **15**, but it is also possible to use only the torque limiting unit **106**, and to omit the units **14** and **15**. In the following description a preferred embodiment is described in which the torque limiting unit **106** is used in addition to the pressure limiting unit **14** and to the flow limiting unit **15**.

In the supporting housing **11**, a third stepped bore **105** is provided, which has a threaded portion **105a** into which a cartridge body **107** is tightly screwed. A measuring piston **108** is slidingly mounted in a stepped bore **109** in the cartridge body **107**. The measuring piston **108** has a central flange **110** and projects the illustrated position of rest, with a pressure pin **112** through an opening forming the narrowest portion of the stepped bore **105**. In this position, the flange **110** abuts an annular shoulder **113** of the stepped bore **105**, as shown in FIG. 2.

The pressure pin **112** is in contact with a double-armed lever **114** which has a turning axis M, and is provided with lateral curved bulges **115**, **116** which are equidistant from the turning axis M. The turning axis M of the lever **114** can be shifted by means of a linkage **117**, **118** which is guided in a guide means **119** for straight movement. The movement of the turning axis M by means of the linkage takes always place in a direction perpendicular to the direction of movement of the measuring piston **108**. Lever **114** is displaced by the linkage **117**, **119** by the differential piston **57** of power amplifier **55** which is connected by a linkage **120** and a connecting member **121** with linkage rod **117**. The position of connecting member **121** can also be varied by a shifting rod **112** guided in guide means **123** for rectilinear movement. The movement of the connecting member **121** is preferably perpendicular to the movement of the differential piston **57**. By means of connecting member **121**, which can be adjusted as desired, the transmission ratio of the linkage means **117**, **118**, **121**, **120** is varied. The above described arrangement effects an adjustment of the axis M of lever **114** proportional to the fluid volume delivered by pump **53**. If the delivered fluid volume is zero, the axis M of lever **114** intersects with the axis of measuring piston **108** in a point.

The bulges **115**, **116** of lever **114** support a one-armed lever plate **124** which is mounted for turning movement about a shaft **125** mounted in bearing portions **126**, **127** whose position can be slightly adjusted so that lever arm plate **124** is slightly slanted with bearing **126** acting as a fulcrum. The projecting pin **51** of tiltable plate **38**, described with reference to FIG. **1**, rests on the lever plate **124** on the outer end remote from shaft **125**. On the top surface of lever plate **124**, a circular track **128** is provided on which rests a roller **129** mounted on a piston **131** which is biassed by a spring **130** and slidingly guided in a lever **132** which has a journal **133** mounted for angular movement in a stationary bearing **134**. The radius of the curved track **128** corresponds to the distance of the curved track **128** from the axis of bearing **134**. Lever **132** has an arm **135** which is either set to a particular angular position which may, for example, correspond to the maximal permissible torque of the combustion engine A, or which is connected with the gas pedal and linkage of the vehicle in such a manner that every rotary speed of the combustion engine A obtained by the driver by operation of the gas pedal, not shown, is associated with a specific drive torque of pump **53**, note FIG. **3**. In the latter case, the direction of travel of the vehicle is preselected by turning the setting lever **97** to the end position, whereupon the vehicle is operated by simultaneously selecting the rotary speed of the combustion engine A, and the torque of pump **103** by means of the gas pedal.

In FIG. **2**, the axis or turning point of lever **114** from the axis of the measuring piston **108** is designated a, and the constant distance of the axis M from bulge **115** is designated b_1. The respective lever arms correspond to a particular position of the differential piston **57** of the power amplifier **55**.

The force P_F of spring **130**, and the turning moment acting on the lever plate **124** is independent of the position of the turning point or axis M of lever **114**, as far as magnitude is concerned. The counter moment results from the force acting on measuring piston **108** multiplied by the length of lever arm a and is proportional to the fluid volume delivered by pump **53**. The force acting on measuring piston **108** is a product of the surface fm of the measuring piston **108** on which pressure acts, multiplied by the fluid pump pressure p. The required condition for a regulation of the torque is pressure of the delivered fluid p multiplied by the volume of the delivered fluid is constant. This condition is obtained in the present case if $p.fm.a = P_{Fr}.b_1$, wherein P_{Fr} constitutes the force of spring **180** reduced to the engaging points of bulges **115** or **116** between lever plate **124** and lever **114**.

The pressure p of the transported fluid is supplied to the measuring piston **108** through a channel **37**, as described with reference to FIG. **1**. If during rising of the fluid pressure, the turning moment $t.fm.a$ exceeds the turning moment $P_{Fr}.b_1$, lever **114** is turned in clockwise direction as viewed in FIG. **2**. Bulge **115** engages and raises the lever plate **124** which raises the right end of tiltable plate **38** by engaging projecting pin **51.** The tilted plate **38** displaces the limiting piston **42** of the limit valve **40** in upward direction, whereupon the differential piston **57** of the power amplifier **55** operates the adjusting means **54** of pump **53** to move toward the left for obtaining a shorter piston stroke, as explained above in the description of the operation of the pressure limiting unit **14.** Pump **53** may be an axial piston pump with a swash plate on which the piston shoes slide, and whose angular position is varied by the adjusting means **54** upon displacement of differential piston **57**, the lever arm *a* being shortened due to the operation of the linkage **117, 118, 121, 120.**

In the event that the pressure of the pumped fluid drops, the turning moment $P_{Fr}.B_1$ is greater than the turning moment *p.fmla*, lever plate **124** is angularly displaced in clockwise direction, and the limiting piston **42** of the limiting valve **40** is returned to its initial position of rest by angular displacement of lever plate **124** and of tiltable plate **38.** The limit of the maximal torque can be adjusted by turning lever **132** so that the turning moment of the force of spring **130** on the axis of lever plate **124** is varied between zero and maximum. The curvature of the curved track **128** is selected so that upon turning of lever **132**, the pretension of spring **130** is not changed, or only slightly changed. In other words, the curvature of the curved track is substantially in accordance with a segment of a circle whose radius corresponds to the distance of the curved track **128** from the axis of journal **133** and bearing **134.** The turning moment acting on the lever plate **124** is zero when the force acting on roller **129** is directed through the axis of lever plate **124** defined by bearings **126, 127** and journals **125.** This turning moment rises as lever **132** is turned a greater angle which means that the point where the force of spring **130** acts, is displaceable along the lever plate **124.**

When the flow direction of pump **53** is reversed by passing through the position in which no fluid is pumped, lever **114** acts through bulge **116** on the lever plate **124** upon starting of the limiting of the torque, due to the fact that the turning point or axis M is now located on the left of the axis of the measuring piston **108**, as viewed in FIG. **2.** The function of the torque limiting unit **106** is not changed in any manner. When the torque limiting unit **106** responds to an increased torque, pump **53** is set to a smaller volume of delivered fluid.

In vehicles with hydrostatic transmissions, as described above, during braking by the inertia of the prime mover combustion engine A, over rotation must be prevented. This can be accomplished in a simple manner by the apparatus of the invention, as will be described with reference to FIG. 3.

A gas pedal **135** is turnable about a stationary bearing **136**, and has an arm **137** on which a spring **137*a*** acts to move gas pedal **135** to a normal position abutting a stop. Two rods **138, 139** are articulated to arm **137.** Rod **139** is connected with the regulator **140*a*** of the injection pump **140** of the combustion engine A, while the rod **138** carries a guide **141** with a slot **142** in which a rod **143** is located. Rod **143** also passes through a slot **144** in a guide member **145** which is connected by a link **146** with an arm of a double-armed brake pedal **148** which is mounted for turning movement in a stationary bearing **149**, and is urged by a spring **148*a*** to a normal position abutting a stop. A resilient connector forms part of the link **146**, which also carries an abutment **146'** cooperating with an adjustable stop **150.**

The vehicle is provided with a conventional friction brake **151** which has a brake cylinder **151** connected by a conduit **152** with a master brake cylinder **153.** Master brake cylinder **153** includes a spring loaded contact pin **154.**

During travel of the vehicle due to the torque produced by combustion engine A, and transmitted by the variable transmission **53, 102** to the wheel **103**, the drive power is selected as usual by depression of the gas pedal **135** which acts through rod **139** on the regulating means **140*a*** of the injection pump **140**, and also acts through rod **138** with guide **141** and slot **142**, on rod **143** and on lever **132**, described in detail with reference to FIG. **2.** If the vehicle is to be braked, the driver releases the gas pedal **135** so that a spring **132''** retracts lever **132** to the illustrated position in which the pump torque is zero. The force of spring **130** extends along a line through the bearing **127** of the lever plate **124.** The vehicle rolls without being driven or braked. The pressure in the hydrostatic transmission **53, 102** drops substantially to the pressure of the low pressure side of the pump. When the drive now operates the brake pedal **148**, the rod **146** sets lever **132** to a torque which is greater than zero. The at first small drag pressure in the hydrostatic transmission **53, 102** rises, and the vehicle speed is reduced.

It is possible to increase the brake effect until abutment **146'** of rod **146** engages stop **150.** In this position, the selected and set maximum torque is equal to the maximum permissible drag torque of the combustion engine A. If even stronger braking is required, further depression of the brake pedal **148** results in engagement of the actuator pin **154** of the piston of the master brake cylinder **153** so that the friction brake **151** is operated. To permit such further angular displacement of the brake pedal **148**, linkage **146** is provided with the resilient connector means **147.**

FIG. **4** illustrates a modifiction of lever **114** which was described with reference to FIG. **2.** In the embodiment of FIG. **4**, a bar **156** carries two spaced rollers **157, 158**, which corresponds to the bulges **115, 116** of lever **114**, and are in contact with the lever plate **124** so that the friction of the mechanism is reduced.

The torque limiting arrangement described with reference to FIG. **2**, can be simplified as shown in FIGS. **5*a*** and **5*b*.** The straight guiding means **123** of connecting member **121** is replaced in the embodiment of FIGS. **5*a*, 5*b*** by a stationary straight guide **159** engaged by a lever **160**, which replaces lever **114.** Lever **160** includes a bar **161** with a central bulge **162** which abuts the straight guide means **159.** Bar **161** carries two pairs of rollers **164** to **167** on opposite sides which engage the lever plate **124** into whose slot **163** the straight guide means **159** projects. The rollers **164** to **167** are in rolling engagement with the bottom face of lever plate **124.** A torque limiting unit modified as shown in FIGS. **5*a*** and **5*b*,** operates as a pressure limiting unit with a characteristic graph raising toward zero, if the straight guide means **159** is raised to a higher level in which it is not engaged by bulge **162.** If lever plate **124** is slightly tilted about the axis of bearings **126, 127**, see FIG. **2**, the pressure of pump **53** rises with a decrease of the delivered volume of fluid.

As shown in FIG. 6, the variable load on lever plate 124 can be obtained by hydraulic means, instead of by spring 130.

The lever plate 124' is supported with journals 125' in stationary bearings for angular movement. At the free end of lever plate 124', a hydraulic cylinder and piston motor 168 acts to which fluid is supplied by an auxiliary pump 170. The pressure exerted by the cylinder and piston means 168 is determined by a settable pressure limiting valve 169 which discharges if the pressure in the cylinder and piston means 168 rises above a maximum.

If in the embodiment of FIG. 2, the torque limiting unit 106 is replaced by a flow limiting unit 15 of the type described with reference to FIG. 1, the straight guide means 119 of the rod 118 is removed. When lever plate 124 is turned about the bearins 126, 127 to a slanted position, a remote control of the differential piston 57 of the power amplifier 55 is possible.

For this purpose, the pressure chamber 28'' of the flow limiting unit 15 is releived, and the lower pressure chamber 28' is supplied with fluid from a channel 179 in the cartridge body 24 which must be connected with the conduit containing pressure fluid. Channel 37 must be closed. To each control pressure, a particular position of the differential piston 57 of the power amplifier 55 is correlated in which positions a reduced force P_{Fr} of spring 130, see FIG. 3, and the pressure force acting on the stepped piston 26 of the flow limiting unit 15 are in equilibrium. If the control pressure is sufficient, the remote control can be used for pump 53 pumping the fluid in forward and reverse directions.

The several described limiting units become regulators if the control slide 71 of the control valve 69 is not centered by springs 81, 82 acting on the ends of control slide 71, but is pretensioned in only one direction by spring 96, or by springs 171, 172 shown in FIG. 1 to act in opposite directions on the setting lever 97.

For the sake of clarity, conduits have been shown as single lines, but it will be understood that such conduits may be pipes, or channels or ducts in the supporting housing means 11. One or several limiting units can be combined in an apparatus according to the present invention, depending on the desired control or regulating function. Instead of pump 53, an adjustable hydraulic motor can also be controlled or regulated. The pressure and torque regulations is effective during operation of a hydraulic machine as pump or motor operating for pumping the fluid in forward or reverse directions so that four operating conditions are possible.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of control apparatus for a hydraulic machine differing from the types described above.

While the invention has been illustrated and described as embodied in a control apparatus for a hydraulic machine including detachable pressure limiting, flow limiting, and torque limiting units, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can be applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended wihin the meaning and range of equivalence of the folliwing claims:

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

I claim:

1. Hydraulic control apparatus for a hydraulic machine having adjusting means for regulating the quantity of fluid transported by said hydraulic machine, comprising in combination, pressure responsive power amplifier means for operating said adjusting means, and having power chamber means, control valve means including a movable valve slide forming pressure chamber means communicating with said power chamber means; manually operated setting means connected with said valve slide for setting said valve slide to different control positions for actuating said power amplifier means to operate said adjusting means so that the hydraulic machine is adjusted in accordance with the selected position of said setting means; supporting means having a plurality of attaching portions; a plurality of limiting units for limiting different flow conditions, and communicating with said hydraulic machine, each limiting unit having a position of rest and an operative position, and moving to said operative position when an undesirable flow condition occurs, at least one of said limiting units being detachably and exchangably mounted in a selected one of said attaching positions; a transmitting device mounted on said supporting housing in the region of said attaching portions, and being moved to an actuated position by any limiting unit attached to any of said attaching portions and being in said operative position, whereby more than one limiting unit can be mounted on said attaching portions for moving said transmitting device, and a limiting valve including a limiting piston operated by said transmitting device in said actuated position to control the flow of fluid in said control valve means so that fluid from said control valve means actuates said power amplifier means to operate said adjusting means to reduce the quantity of fluid transported by said hydraulic machine.

2. Control apparatus as claimed in claim 1, wherein one of said limiting units is a pressure limiting unit, a second limiting unit is a flow volume limiting unit, and a third limiting unit is a torque limiting unit.

3. Control apparatus as claimed in claim 1, wherein each of said attaching portions includes a threaded bore; and wherein each of said limiting units includes a body having an outer thread matching the thread of said threaded bores.

4. Control apparatus as claimed in claim 3, wherein at least one of said limiting units includes a bore, and a measuring piston in said bore movable between said position of rest and said operative position.

5. Control apparatus as claimed in claim 1, wherein a first limiting unit is a pressure limiting unit; wherein a second limiting unit is a flow volume limiting unit; wherein a third limiting unit is a torque limiting unit; wherein said three limiting units are mounted in three attaching portions, respectively,; wherein said transmitting means includes a first transmitting means engaged by said first and second limiting units and operated by the same to displace said limiting piston, and a second transmitting means engaged and operated by said third limiting unit, and operatively connected with said first

transmitting means to operate the same to displace said limiting piston.

6. Control apparatus as claimed in claim 1, wherein a first limiting unit of said limiting units is a pressure limiting unit including a body forming a cylinder bore and mounted on a first attaching portion, a measuring piston forming in said cylinder bore, a pressure chamber communicating with said hydraulic machine, and a first spring biasing said measuring piston against the pressure of fluid in said pressure chamber; and wherein said measuring piston has a pin portion projecting out of said body for operating said transmitting device.

7. Control apparatus as claimed in claim 6, wherein a second limiting unit is a flow volume limiting unit including a second body mounted on a second attaching portion and forming a second cylinder bore, a second measuring piston mounted in said second cylinder bore and forming two second pressure chambers in said second cylinder bore; a high pressure conduit connected with said hydraulic machine; a throttle in said conduit; wherein one of said second pressure chambers receives high pressure fluid from said conduit upstream of said throttle and the other second pressure chamber receives fluid from said conduit downstream of said throttle; and a second spring biasing said second measuring piston; and wherein said second measuring piston has a second pin portion projecting out of said second body for operating said transmitting device.

8. Control apparatus as claimed in claim 7, wherein each of said attaching portions of said supporting means includes a threaded bore; wherein said bodies of said first and second limiting units have outer threads threaded into said threaded bores; wherein said first and second springs having ends abutting the bottoms of said threaded bores so that the tension of said springs is adjusted by screwing said bodies into said threaded bores, respectively.

9. Control apparatus as claimed in claim 7, wherein said supporting means has an abutment surface; wherein said transmitting device includes a transmitting plate having on opposite ends on the bottom face fulcrum bulges resting on said abutment surface; wherein said pin portions abut said bottom face at said ends; wherein said limiting piston is spring biased toward said transmitting plate and engages the top surface thereof equidistant from said ends whereby when anyone of said pin portions displaces the respective end of said transmitting plate, the same is turned about the fulcrum bulge at the respective other end so that said limiting piston is operated.

10. Control apparatus as claimed in claim 9, wherein a third limiting unit is a torque limiting unit having a third body mounted on a third attaching portion of said supporting means and forming a third cylinder bore; a third measuring piston in said third cylinder bore forming a third pressure chamber in the same communicating with said hydraulic machine; wherein said third measuring piston has a third pin portion projecting out of said body for operating said transmitting device.

11. Control apparatus as claimed in claim 10, wherein said transmitting device further includes a double armed lever engaged by said third pin portion and having projections at the ends thereof, linkage means controlled by said power amplifier means for moving said lever perpendicularly to the direction of movement of said third pin portion, a lever arm mounted for angular movement about an axis, biasing means for biasing said lever arm to engage said projections, said lever arm having a free end resting on said projections, and means connecting said lever arm with said transmitting plate for operating said limiting valve means.

12. Control apparatus as claimed in claim 11, wherein said biasing means include a cylinder, a spring in said cylinder, and a piston biased by said spring and acting on said lever arm.

13. Control apparatus as claimed in claim 12, wherein said transmitting device includes means mounting said biasing means for movement along said lever arm for continuously varying the biasing force acting on said double armed lever.

14. Control apparatus as claimed in claim 13, wherein said lever arm includes a curved guide track for guiding said piston of said biasing means; and wherein said mounting means support said biasing means for angular movement along said guide track.

15. Control apparatus as claimed in claim 11, wherein said linkage means support said double armed lever for angular movement about an axis equidistant from said projections thereof so that said double armed lever can be displaced by said power amplifier means.

16. Control apparatus as claimed in claim 11, comprising a linkage operatively connecting said manually operated setting means with said biasing means for varying the point of engagement of said biasing means with said lever arm.

17. Control apparatus as claimed in claim 11, comprising a combustion motor for driving said hydraulic machine and having a gas pedal; and a linkage operatively connecting said gas pedal with said biasing means for varying the point of engagement of said biasing means with said lever arm.

18. Control apparatus as claimed in claim 11, including shaft means for mounting said lever arm for angular movement; and means for gradually slanting said shaft means.

19. Control apparatus as claimed in claim 11, comprising a vehicle having wheels and supporting said hydraulic machine; said hydraulic machine being a pump; a hydraulic motor driven by said pump and driving said wheels; a friction brake operable for braking said wheels and including a brake pedal; and linkage means connecting said brake pedal with said biasing means for varying the point of engagement of said biasing means with said lever arm.

20. Control apparatus as claimed in claim 1, wherein said setting means include first and second linkage means connected with said valve slide and with said power amplifier means, respectively, a manually operated member; and resilient connecting means connecting said first and second linkage means with said manually operated member so that said power amplifier means can adjust said adjusting means under the control of said limiting units without displacing said manually operated member.

21. Control apparatus as claimed in claim 20, wherein said valve means includes springs acting on the ends of said valve slide for urging the same to a central position.

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