Dec. 16, 1969 KAZUO SUGIMURA ET AL 3,483,892

HYDRAULIC CONTROL UNIT

Filed Jan. 30, 1968

Fig. 1a.

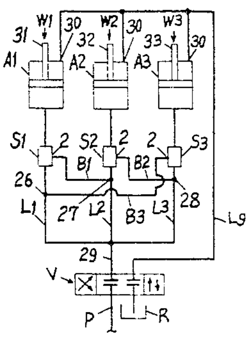


Fig. 1b.

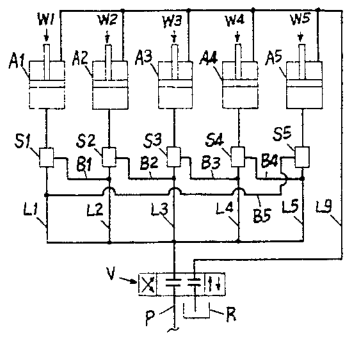


Fig. 7a.

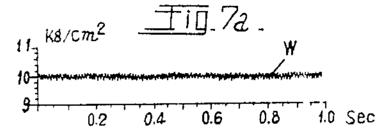


Fig. 7b.

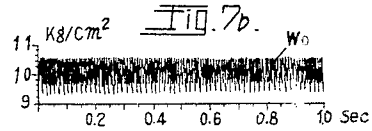


Fig. 2.

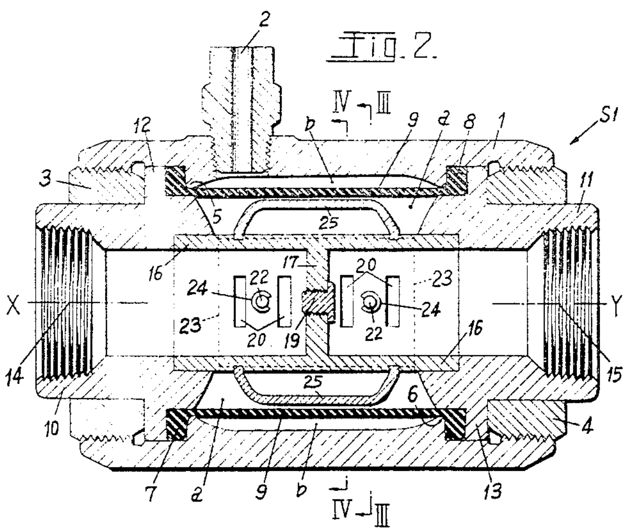


Fig. 3.

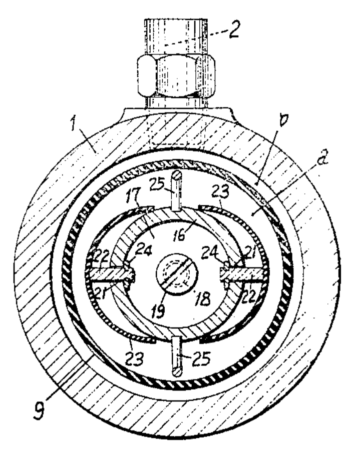


Fig. 4.

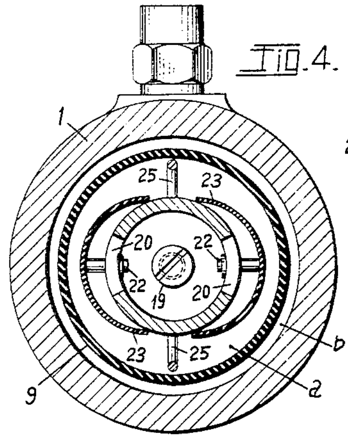


Fig. 5.

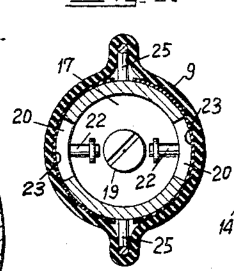
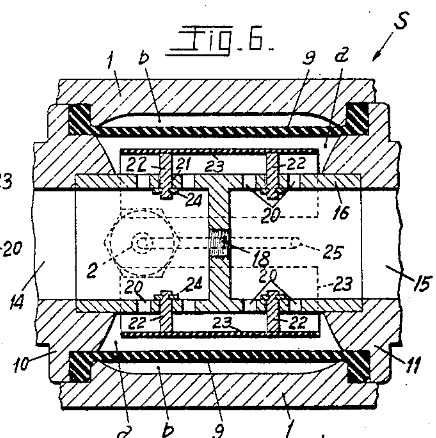


Fig. 6.



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United States Patent Office 3,483,892 Patented Dec. 16, 1969

3,483,892
HYDRAULIC CONTROL UNIT

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Filed Jan. 30, 1968, Ser. No. 701,706
Claims priority, application Japan, Apr. 28, 1967, 42/27,488
Int. Cl. F15b 11/20
U.S. Cl. 137—601 5 Claims

ABSTRACT OF THE DISCLOSURE

A rigid generally tubular body has inner and outer wall portions defining an annular space and has a transverse partition across its interior through which there is a hole that can be plugged. A resilient tubular membrane, its end portions confined between body parts, divides said space into an outer annular chamber communicated with the body exterior through a port and a concentric inner annular chamber communicated with the body interior through port means at opposite sides of the partition. Resilient valve shoes of arcuate transverse section overlie the inner wall portion to cooperate therewith in defining crescent-shaped passages connecting the port means around the partition. Constriction of the tubular membrane, under pressure difference between the chambers, moves the valve shoes radially inwardly to throttle the passages.

This invention relates to control apparatus for hydraulic systems, and more particularly to a hydraulic unit which is in the nature of a pressure compensating valve and which is adapted for cooperation with other similar units to provide a type of flow divider by which a plurality of hydraulic motors connected with a common presure fluid source can be caused to operate at equal speeds, the unit being also adaptable to serve for damping liquid hammer in a pressure fluid circuit.

When pressure fluid from a single source is simultaneously supplied to a plurality of hydraulic motors through branched ducts, the motors, if differently loaded, tend to operate at different rates of speed, the relative speeds of the motors being generally in inverse relationship to their loads. Motors so connected can be constrained to operate at equal speeds by means of a mechanical linkage between them. It is also possible to cause them to operate at equal speeds by controlling flow of fluid to them by means of suitable valves in the duct branches, controlled by electrical or other detecting means responsive to speed differences between the motors.

By contrast with these known expedients, it is an object of this invention to provide simple means for causing a plurality of hydraulic motors connected with a common pressure fluid source to operate at equal without the need for mechanical linkages between them or any sort of speed responsive detector means.

It is also an object of the present invention to provide a hydraulic control unit which is in the nature of a pressure compensating valve and which can be combined with other similar control units to provide apparatus which serves as a kind of flow divider by which pressure fluid from a single source thereof can be so controlled in its flow simultaneously to each of a plurality of hydraulic motors as to cause all of the motors to operate at the same speed, regardless of differences in their loads.

Another object of this invention is to provide an improved automatic throttling valve for producing a pressure drop in one part of a hydraulic circuit that varies in accordance with the relationships of load conditions in other parts of the circuit to one another and to pres-

sures obtaining at the source of pressure fluid for the system.

It is a further object of this invention to provide a hydraulic control unit of the character described which is readily adaptable to employment as a damper for eliminating liquid hammer in hydraulic systems.

With these observations and objects in mind, the manner in which the invention achieves its purpose will be appreciated from the following description and the accompanying drawings. This disclosure is intended merely to exemplify the invention. The invention is not limited to the particular structure or method disclosed, and changes can be made therein which lie within the scope of the appended claims without departing from the invention.

The drawings illustrate two complete examples of the physical embodiment of the invention constructed according to the best modes so far devised for the practical application of the principles thereof, and in which:

FIGURE 1*a* is a schematic diagram of a hydraulic circuit having three hydraulic motors that are supplied with pressure fluid from a common source and embodying hydraulic control units of this invention cooperating to cause the motors to operate at equal speeds;

FIGURE 1*b* is a schematic diagram which is generally similar to FIGURE 1*a* but which illustrates a circuit having five hydraulic motors;

FIGURE 2 is a longitudinal sectional view of a hydraulic control unit embodying the principles of this invention and adapted for incorporation in circuits such as those of FIGURES 1*a* and 1*b*;

FIGURE 3 is a transverse sectional view taken on the plane of the line 3—3 in FIGURE 2;

FIGURE 4 is a transverse sectional view taken on the plane of the line 4—4 in FIGURE 2;

FIGURE 5 is a view on a smaller scale, generally corresponding to FIGURE 4 but showing the unit with its valve shoes closed;

FIGURE 6 is a longitudinal sectional view of a control unit of this invention slightly modified to adapt it for use as a liquid hammer damper;

FIGURE 7a is an oscillogram trace graph of noise in a hydraulic circuit wherein there is installed a liquid hammer damper comprising the control unit of this invention; and

FIGURE 7*b* is a diagram similar to FIGURE 7*a* but showing conditions in the same circuit without a noise damper.

Referring now to the accompanying drawings, and more particularly to FIGURES 2–5, the control unit of this invention, which is generally designated S1, comprises a tubular outer body member 1 having intermediate its ends a laterally opening port 2 comprising a nipple or the like that provides for connection to a hydraulic or pressure gas duct as explained hereinafter. Within the outer body member there is a tubular membrane 9 of resilient rubber-like material having radially outwardly projecting circumferential flanges 7 and 8 on its opposite ends. The flange 7 on the membrane tube is compressively confined between an axially outwardly facing circumferential shoulder 5 in the interior of the outer body member and a tubular bushing 10 that is received in one end portion of the outer member. A threaded ring 3 cooperates with the outer body member and the bushing 5 to maintain the latter in compressive engagement with the membrane flanges. The flange 8 on the membrane is similarly confined against a shoulder 6 in the outer body member by means of a tubular bushing 10 and a threaded ring 4.

Specifically, considering the leafhand portion of the unit by way of example, the bushing 10 has a radially outwardly projecting circumferential flange 12 which is spaced a short distance axially from its inner end and which provides an axially inwardly facing circumferential shoulder that bears against the flange 7 on the tubular membrane. The threaded ring 3 is received in the internally threaded end portion of the outer body member 1 and surrounds the axially outer portion of the bushing 10, with its inner end bearing against the axially outer face of the flange 12 on the bushing to maintain compressive force thereon.

It will be understood that the arrangement of the bushing 11, which has a flange 13, is the counterpart of that just described.

The bore through each of the tubular bushings 10 and 11 terminates at its outer end in an enlarged internally threaded mouth, as at 14 and 15 respectively, that is adapted for connection with a pressure fluid duct. Either of the threaded mouths 14 or 15 can provide an inlet to the unit for pressure fluid flowing from a source thereof, while the other provides an outlet through which such pressure fluid can flow to a hydraulic motor.

Each of the bushings 10 and 11 has the inner end of its bore enlarged to accommodate a cylindrical inner body member 16, which is thus conjointly supported by the two bushings and is coaxial with them and with the outer body member 1. Intermediate its ends the inner body member has a partition 17 extending thereacross. A plug 19 closes a hole 18 through the partition 17 when the unit is used for controlling the speed of one of a plurality of hydraulic motors, but the plug can be removed to adapt the unit for use as a liquid hammer damper.

The outside diameter of the inner body member 16 is substantially smaller than the inside diameter of the outer body member 1 so that there is substantial radial spacing between the body members. The tubular membrane 9 divides the annular space between the outer and inner body members 1 and 16 into two concentric annular chambers, namely an inner chamber *a* and an outer chamber *b*. Since the membrane is imperforate, there is no communication between these chambers. However, the outer chamber *b* is communicated with the port 2 that opens laterally from the outer body member 1, and the inner chamber *a* is communicated with the interior of the inner body member 16 through ports 20 that open through the wall of the inner body member at both sides of the partition 17 therein. Fluid of course flows through the unit by way of the ports 20 and the inner chamber *a*, in bypass relation to the partition 17, and it is in the course of such flow that automatic throttling takes place, as will be apparent from the following description.

As best seen from FIGURE 2, the ports 20 are aligned in axially extending rows at diametrically opposite sides of the inner body member 16. In the inner chamber *a*, overlying the ported portions of the inner body member at its opposite sides, are valve shoes 23 of resilient rubber-like material, each extending nearly the full length of the inner chamber *a* and each having an arcuate cross section which is normally of smaller radius than the inner body member. Normally, therefore, each valve shoe has only its longitudinal edges engaged with the inner body member, and it defines therewith a passage of crescent-shaped cross-section connecting ports 20 at one side of the partition 17 with ports 20 at the other side thereof. But each valve shoe can be flexed radially inwardly all the way to a position snugly overlying the outer surface of the inner body member and thus blocking flow through the ports 20. In intermediate positions of its flexing the valve shoe provides for more or less throttled flow of fluid through the crescent-shaped passage that it defines.

Each valve shoe is maintained in its proper location and guided in its flexing motion by means of a pair of guide stems 22 that extend radially through the inner body member 16, one at each side of the partition 17, each slidably guided in a hole in the wall of the inner body member that is axially in line with the ports 20. A C-ring 24 on the inner end of each guide stem 22 provides an enlarged head that prevents the guide from slipping out its hole.

Between each pair of opposing longitudinal edges of the two valve shoes a bail-like guide bar 25 is secured to the inner body member 16, to provide diametrically opposite radially outwardly projecting axially extending ridges.

When fluid pressure in the outer chamber *b* exceeds that in the inner chamber *a*, the tubular membrane is contracted radially inwardly by the pressure difference. Because of the presence of the guide bars 25, such contraction of the tubular membrane causes it to bear against the portions of the valve shoes that are intermediate their longitudinal edges, and to force the valve shoes radially inwardly toward their port closing positions illustrated in FIGURE 5. As each valve shoes is thus flexed toward a large radius of curvative, its longitudinal edges must slide circumferentially around the outer surface of the inner body member 16. The guide bars 25 hold the tubular membrane out of engagement with these edge portions of the valve shoes so that the tubular membrane does not interfere with such sliding action.

It will also be apparent that provision of the guide bars 25 enables contraction of the tubular membrane to take place without any twisting or other straining distortion thereof, and thus permits the membrane to contract and expand without fatigue or undue stresses that might result in its rupture or in leakage through its connections with the rigid parts of the unit.

Under the conditions illustrated in FIGURE 5, wherein there is a much higher pressure in outer chamber *b* than in the interior of the inner body member, the valve shoes 23 completely block flow through the ports 20. There is of course a range of pressure differential conditions in which the tubular membrane 9 and the valve shoes 23 are intermediate their conditions shown in FIGURES 4 and 5 and in which more or less throttled flow can take place from the ports 20 at one side of the partition 17 to the ports 20 at the other side of said partition. The amount of throttling that will be imposed upon such fluid flow will of course depend upon the value of the pressure differential between the chambers *a* and *b*.

FIGURE 1*a* shows how a plurality of the units of this invention, designated S1, S2, S3, are arranged to cooperate to constrain three hydraulic motors A1, A2, A3, connected with a common source P of pressure fluid, to operate at equal rates. The line P which represents the pressure fluid source is connected with a conventional control valve V, and a duct 29 leading from the high pressure outlet port of the valve V has three branches L1, L2, L3 which respectively connect with the pressure fluid inlets of the units S1, S2 and S3. The pressure fluid outlets of these units are respectively communicated with the pressure inlet ports of hydraulic motors A1, A2 and A3. The motors are represented as conventional cylinders, having pistons 31, 32 and 33, respectively, and having return fluid ports 30 that are communicated with a manifolded return fluid duct L9 which in turn connects with the return fluid port of the valve V and is communicable through that valve with the reservoir R.

The laterally opening port 2 of each unit S1, S2, S3 is communicated with the pressure fluid inlet of another unit. Thus the port 2 of the unit S1 is communicated by means of duct B1 with the branch duct L2 that connects with the pressure fluid inlet of unit S2; and similarly duct B2 communicates port 2 of unit S2 with branch duct L3, while duct B3 communicates port 2 of unit S3 with branch duct L1.

Assume now that motor A1 bears a relatively light load W1, motor A2 has a load W2 of intermediate value and motor A3 has a heavy load W3. Further, assuming that motor A1 is in very rapid motion, the fluid pressure in inner chamber *a* of unit S1 will be very low, whereas fluid pressure in the outer chamber *b* of that unit will be at a relatively high value, substantially corresponding to that at the pressure fluid inlet to unit S2, in branch duct L2. Under these conditions of relatively high pressure difference between chambers *a* and *b* of unit S1, its tubular membrane **9** is constricted toward the condition illustrated in FIGURE 5, forcing its valve shoes **23** towards blocking relationship with its ports **20**; and, in fact, there might be a momentary blockage of fluid flow through the unit to stop operation of motor A1 while motors A2 and A3 catch up with it.

In consequence of such assumed momentary blockage of flow to motor A1, fluid pressure rises in branch duct L1 and therefore also in the inner chamber *a* of unit S1, whereas fluid continues to flow in duct L2 to which the outer chamber *b* of unit S1 is connected through duct B1. With decreasing difference in the pressure differential between chambers *a* and *b* of unit S1, the tubular membrane **9** of that unit expands radially, releasing its valve shoes **23** from the surface of its inner body member **16** to permit fluid flow through that unit to resume. During the interval of closure of unit S1, the relatively high pressure in branch duct L1 is manifested in an increased pressure in the outer chamber *b* of unit S3, causing a constriction of the membrane **9** of that unit, thus effecting some throttling of the fluid flow therethrough. In turn this causes a pressure rise in branch duct L3, which is reflected, after a brief time delay, in a pressure increase in the outer chamber *b* of unit S2, by way of its connecting duct B2, causing that unit to effect some throttling of the flow therethrough.

There is thus a chain reaction through the system by which it is caused to seek an equilibrium condition at which all of the motors A1, A2 and A3 tend to operate at the same speed.

FIGURE 1*b* illustrates apparatus having five motors A1–A5 supplied from a common pressure fluid source, each connected with the source through one of the units S1–S5 of this invention. It will be apparent that the apparatus of FIGURE 1*b* embodies the principles explained in connection with FIGURE 1*a*.

As illustrated by FIGURE 6, the unit of this invention is readily adaptable for use as a noise damper for hydraulic circuits simply by removing the plug **19** from the hole **18** through the partition **17** across the inner body member, so that hydraulic pressure fluid can flow relatively freely through the unit. When the unit is used for noise damping, the outer chamber *b* is charged with gas under pressure through the port **2**, and preferably the pressure of such gas is high enough so that the tubular membrane **9** is normally fully constricted to the condition illustrated in FIGURE 5, at which the valve shoes are forced into full engagement with the inner body member **16** to block flow of fluid through the ports **20**.

Liquid hammer and turbulent noise can occur in a hydraulic circuit when a valve in the circuit is shifted to cause an abrupt cessation of pressure fluid flow and a consequent abrupt increase in fluid pressure upstream from the valve. When it develops, liquid hammer not only results in annoying noise but can be injurious to measuring instruments connected with the hydraulic system and can cause vibration in the circuit components and possible leakage or rupture.

With the unit of this invention in a hydraulic system, modified as shown in FIGURE 6, any abrupt increase in fluid pressure in the unit results in a radial expansion of the tubular membrane against the pressure gas in the outer chamber *b*, effecting an opening of the ports **20** and allowing a temporary entry of pressure fluid into the inner chamber *a* by which the surge of fluid pressure is accommodated and minimized and by which vibration is eliminated.

The effects upon vibration in a hydraulic system due to installation therein of the unit of this invention, modified as shown in FIGURE 6, can be seen from a comparison of FIGURES 7*a* and 7*b*, wherein vibration in the system without liquid hammer arresting means is depicted by *Wo* in FIGURE 7*b* while vibration in the same system, but embodying the unit of this invention, is depicted by W in FIGURE 7*a*.

From the foregoing description taken with the accompanying drawings, it will be apparent that this invention provides a simple, inexpensive and versatile hydraulic unit that can be combined with other similar units to provide a type of flow divider by which several hydraulic motors connected with a common pressure fluid source can be caused to operate at equal speeds, and which is readily adaptable for use as a liquid hammer arrester.

We claim:

1. A hydraulic control unit of the character described comprising:

(A) means defining a generally tubular body having concentric inner and outer wall portions between which there is an annular space, said body having
  (1) a port in its outer wall portion opening from said annular space, and
  (2) lengthwise aligned spaced apart port means in its inner wall portion;

(B) a generally tubular resilient membrane having its end portions sealingly connected with axially spaced portions of the tubular body and normally dividing said space into
  (1) an inner chamber communicable through said port means with the interior of the body, and
  (2) an outer chamber communicable through said port with the exterior of the body;

(C) a resiliently flexible valve shoe of arcuate transverse section within the inner chamber, overlying the inner wall portion of the body and extending axially and circumferentially beyond the port means, said valve shoe being normally curved on a radius smaller than that of said inner wall portion to cooperate therewith in defining a crescent-shaped passage through which said port means are communicable with one another, said valve shoe being resiliently deformable into snug engagement with said inner wall portion to close the port means, in consequence of radial contraction of the membrane; and

(D) means cooperating with the inner wall portion and the valve shoe to constrain the latter to motion radially toward and from snugly overlying engagement with the outer surface of the inner wall portion.

2. The hydraulic control unit of claim **1**, further characterized by:

a transverse partition across the bore of the tubular body by which pressure fluid entering one end of the tubular body is constrained to flow through said port means and said crescent-shaped passage for flow out of the other end of the tubular body.

3. The hydraulic control unit of claim **2**, further characterized by:

(A) said partition having a hole therethrough to provide for direct flow of pressure fluid from one end to the other of the bore in the tubular body; and

(B) plug means removably receivable in said hole.

4. The hydraulic control unit of claim **1**, further characterized by:

said means for constraining the valve shoe to radial motion comprising a pair of stems connected with the valve shoe intermediate its longitudinal edges and slidably guided in axially spaced holes in the inner wall portion of the body.

5. The hydraulic control unit of claim **1**, further characterized by:

substantially rigid means on the inner wall portion projecting radially outwardly therefrom and extending lengthwise in both directions beyond said port means, said rigid means providing ridges on the inner wall portion that are normally spaced circumferentially from the longitudinal edges of the valve shoe and which hold the tubular membrane, when it constricts, out of engagement with the longitudinal edge portions of the valve shoe to allow the same to slide circumferentially around the outer surface of the inner wall portion.

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U.S. Cl. X.R.

60—97; 91—412; 92—41; 137—100; 251—5, 61.1