Fig. 6

Fig. 7

Fig. 8

Fig. 9

17 Vent holes
Bunsen type valve

20 Cap

21 Vents
Master Cylinder Type Valve

Flapper Valve

19 Container

22 Drying Agent

23 Porous Plug

18 Conduit

7 Filler Cap

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This invention relates to hydraulically-actuated systems, force-transfer systems, and more particularly to methods and means for inhibiting water accumulation therein.

Modern hydraulically-actuated systems, especially automotive hydraulic braking systems, require absolute freedom from gassing and decomposition of the fluid at the operating conditions. Various hydraulic fluids are available which, when first employed in a hydraulically-actuated force-transfer system, have sufficient high boiling points so that no gassing or vaporization occurs, but after considerable periods of use, gassing or "vapor-lock" takes place under severe operating conditions with consequent improper functioning.

It has now been found that this gassing or vaporization is the result of a certain amount of water which has accumulated in the hydraulic fluid, reducing its boiling point to a dangerously low figure. Further, the discovery has been made that practically all of the water found in a hydraulic fluid during normal operation of the force-transfer system is absorbed from atmospheric air breathed through the small vent on the hydraulic fluid reservoir of the master cylinder.

It is an object of this invention to inhibit the accumulation of water in a hydraulically-actuated, force-transfer system. It is a further object to provide methods and means of preventing a lowering of the boiling point of hydraulic brake fluids during normal service operation. A still further object is to exclude atmospheric water vapor from a hydraulic brake system. Another object is to inhibit air pulsation through the vent of the master cylinder reservoir during normal actuation of the system.

These and other objects hereinafter apparent are accomplished by this invention, the particular features and advantages of which will be made clear by reference to the accompanying drawings and ensuing description.

In accordance with this invention, the disadvantages of prior operation are overcome and water accumulation in a hydraulically-actuated, force-transfer system is inhibited by passing atmospheric air over a drying agent before it enters the master cylinder fluid reservoir, or by substantially preventing the breathing of air through the fluid reservoir vent on actuation of the system, and preferably by a combination of the above steps of drying entering air and preventing air breathing or pulsation.

A container filled with a drying agent is used to dry the entering air and when employed according to this invention has been found to be extremely effective during an extended operating period, particularly in automobiles. A check valve is used to prevent air breathing or pulsation through the reservoir vent during actuation of the system.

Although the present invention is applicable to any hydraulically-actuated, force-transfer system or mechanism, this invention is especially applicable to automotive hydraulic brake systems, which form a preferred group of hydraulically-actuated, force-transfer systems. Accordingly, the ensuing detailed description is applied thereto, without intending to restrict its scope to the particular details described.

Referring now to the drawings:

Figure 1 represents a conventional automotive hydraulic braking system with the drying container and check valve of the present invention in place upon the fluid reservoir air vent.

Figure 2 represents in sectional form a conventional hydraulic brake master cylinder with a conventional vented filler cap in place.

Figure 3 represents a filler cap with a master cylinder type check valve in place in accordance with the present invention.

Figure 4 represents a conventional filler cap with a flapper type rubber check valve in place.

Figure 5 represents a conventional filler cap with a Bunsen type check valve in place.

Figure 6 represents a filler cap to which is connected the drying container of this invention.

Figure 7 represents the drying container of Figure 6 with a Bunsen type check valve combined therewith.

Figure 8 represents the drying container of Figure 6 with a master cylinder type check valve combined therewith.

In normal operation of the hydraulic brake system, the brake system is filled with hydraulic fluid and, referring to Figure 2, the reservoir 1 is at least partially filled with fluid. The cylinder barrel 2 is provided with a check valve 3 and plunger 4. The reservoir 1 is connected with the cylinder barrel 2 through openings 5 and the reservoir 1 is in turn vented to the atmosphere by vent holes 6. When a brake application is made and the foot pedal 24 of Figure 1 is actuated, a geyser of fluid jets from the cylinder barrel 2 through the opening 5 in front of the primary rubber cup into the reservoir 1. The fluid is thereby aerated by air in the reservoir 1, and at the same time a slight air pressure is built up in the reservoir 1 causing air to leave the vent holes 6. Upon release of the brakes, the master cylinder check valve 3 tends to maintain a slight pressure upon the service conduit 25 in Figure 1. Some fluid is drawn into the master cylinder barrel 2 as the cup passes holes 5 causing air to enter through the vent holes 6 to replace that previously expelled. This air pulsation or breathing action
just described has been found to be the principal cause of moisture condensation and accumulation in a hydraulic brake system. Some air passage through the vent, for which it is intended, also occurs as a result of temperature changes and normal losses of fluid from the system, e.g., seepage around the cups. Figures 3, 4, and 5 show in detail three types of rubber check valves installed in filler plugs.

In Figure 6, a rubber cone 18 is closely fitted in a perforated conical housing 9 being retained by a crimp 10; a baffle 11 is provided to prevent mechanical losses of fluid from the reservoir, and the usual air vents 12 are provided. Referring now to Figure 2, when the rubber check valve assembly of Figure 3 is installed in place of the filler cap 7 of Figure 2, this rubber check valve, in operation, temporarily prevents air from leaving the reservoir 1, and thereby prevents air pulsation with application of the brakes. This pulsating, or "breathing," normally attendant upon brake application is thereby inhibited, and with it the influx of moisture-laden air into reservoir 1 of Figure 2.

Figure 4 shows a conventional filler cap in which two discs of rubber 13 and 14, form a flapper type check valve, the annular disc 13 being attached to the cylindrical disc 14 at one point as shown, so that a closely-fitting continuous contact between the two rubber discs is formed. The operation of this valve assembly which replaces filler cap 7 of Figure 2, is substantially the same as the master cylinder type check valve of Figure 3.

In Figure 5, illustrating a Bunsen type check valve, the ordinary vents (6 of Figure 2) are sealed and a metal tube 15 is fitted with a closed, slotted rubber tube 16 and vented to the atmosphere through vent holes 17. In operation, the Bunsen valve assembly of Figure 5 replaces the conventional filler cap 7 of Figure 2. By replacing the ordinary vented filler cap 7 with a filler cap equipped with a master cylinder check valve as represented by Figure 3 or a flapper type rubber check valve such as represented by Figure 4, or a Bunsen type check valve as represented by Figure 5, the breathing action through the air vent is substantially inhibited and with it, the unnecessary influx of moisture-laden fresh air. Any one of these check valves operates successfully to permit a slight pressure to build up in the reservoir 1 during brake application while permitting the air passage necessary to compensate for temperature-induced volume changes and normal fluid losses resulting from seepage around the cups.

Referring now to Figure 6, a conventional filler cap 7 without the usual vent holes, is attached by a tubular conduit 18 to a container 19. A cap 18 on the container 19 is provided with vents 21 to permit ingress and egress of atmospheric air. The container 19 is filled with a drying agent 22 which may be silica gel, alumina gel, calcium sulfate, activated alumina, calcium chloride, adsorptive carbon or other drying agent. Plugs 23, which may be of cotton or glass wool, finely perforated plates, porous plugs or similar material permitting the passage of gases and vapors, retain the drying agent in place. Referring to Figure 2, the assembly of Figure 6 replaces the filler cap 7 of Figure 2, and it is apparent that in normal braking operations all of the air entering the reservoir 1 of Figure 2 must pass over and through the drying agent 22 of Figure 6. Water as vapor or liquid is inhibited from entering the braking system, during the breathing action above described.

Figure 7 shows a Bunsen type check valve such as previously described in connection with Figure 5, in place on the drying agent container 19 of Figure 6, whereby the air is dried as it enters the reservoir and its egress is retarded. Figures 8 and 9 show respectively a master cylinder type check valve such as described in connection with Figure 3 in place upon the drying container 19 of Figure 6, and a flapper type check valve such as described in Figure 4 in place upon the drying container 19 of Figure 6. Both of these valves function similarly to the Bunsen type check valve of Figure 7 to retard the escape of air, thus preventing the breating of air through the master cylinder vent during brake applications while at the same time permitting normal compensation for changes in air temperature and fluid volume in the reservoir 1.

The following examples illustrate the practice of Example 1. Referring to Figure 6, a metal tube 19 about one inch in diameter and 8 inches long is closed at one end except for a 1/4 inch diameter hole into which a small copper tube 18 is soldered. The 6" x 1" tube 19 is filled with approximately 12 oz. of freshly activated alumina 22 held between two small plugs 16, 17, and the large opening of the tube is closed by means of a metal cap 20 containing two 1/8" breather holes 21. The breather holes in the master cylinder filler cap 7 are soldered shut and a 1/4" copper pipe 18 is soldered into the filler cap. This latter pipe is coupled to the similar pipe on the tubular drying container 19 in such a manner that any air drawn into the master cylinder reservoir 1 of Figure 2 must pass over the alumina 22 and be dried when the drying container assembly is substituted for filler cap 7 of Figure 2.

The brake fluid used was made by reacting 35 parts by volume of castor oil with 15 parts by volume of beta-(methoxymethoxy) ethanol in the presence of 42 grams of potassium ricinoleate catalyst per liter. The complete fluid contained 50 parts by volume of the above reaction mixture and 50 parts by volume of beta-(methoxymethoxy) ethanol with incidental water in the amount of 0.1-0.5%. The gassing temperature of this fluid is about 340°F, which is higher than temperatures encountered under operating conditions. The following results were obtained after several hundred thousand brake applications at temperatures up to 100°F and relative humidities up to 55%:

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Brake applications</th>
<th>Water absorption—Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Master G. T.</td>
<td>Wheel G. T.</td>
</tr>
<tr>
<td>(1)</td>
<td>315,000</td>
<td>0.25</td>
</tr>
<tr>
<td>(2)</td>
<td>600,000</td>
<td>0.20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Brake applications</th>
<th>Water absorption—Protected fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Master G. T.</td>
<td>Wheel G. T.</td>
</tr>
<tr>
<td>(1)</td>
<td>315,000</td>
<td>0.12</td>
</tr>
<tr>
<td>(2)</td>
<td>600,000</td>
<td>0.13</td>
</tr>
</tbody>
</table>

"G. T." is the gassing temperature of the fluid with the water content given. Test number 2
was conducted at an average atmospheric humidity lower than that of test number 1, and consequently the total water absorption was lower than in test number 1.

60,000 strokes are equivalent to at least 60,000 miles of driving. It is evident that the alumina drier holes 12 practically prevents any water absorption by the fluid in the brake system, since the amount found in the protected system is about equivalent to the water introduced during the filling of the brake system.

Example 2.—Referring to figure 5, the usual breather holes in the master cylinder filler cap 7 of Figure 2 are soldered shut, a ¼” hole is drilled through the top of the filler cap, and a ½” x ¼” diameter metal tube 16 is soldered through the filler cap and allowed to extend about ½” on either side of the cap. The end of the tube outside of the cylinder is closed off with solder, and two breather holes 17 about 1/16” in diameter are drilled into the side of the tube. A slit about ¼” long is made in a rubber tube 16 closed at one end and about ½” long, having a diameter that will make a tight connection when fitted over the end of the metal tube 15 extending through the filler cap. The rubber tube is fitted to the metal tube 16, forming an ordinary Bunsen type valve and the assembly is substituted for filler cap 7 of Figure 2. It operates by making it impossible to hold a vacuum on the system, but possible to hold a slight pressure on the system during brake application. In operation, no air is expelled from the reservoir 1 of the master cylinder 2 upon the application of the brakes and, on the other hand, full compensation for changes in air temperature and fluid volume in the reservoir 1 is permitted. The following results were obtained with this device operating with the same fluid as that in the preceding example at temperatures of about 90°F. and 45% relative humidity:

| Test No. | Brake applications | Water absorption—Control Master cyl. G. T. Wheel cyl. G. T. Per cent *F. Per cent *F. |
|---------|-------------------|--------------------------|---------------------|---------------------|
| (1)     | 276,000           | 0.28                     | 218                  | 0.76                |
| (2)     | 600,000           | 0.26                     | 315                  | 0.76                |

| Test No. | Brake applications | Water absorption—Protected fluid Master cyl. G. T. Wheel cyl. G. T. Per cent *F. Per cent *F. |
|---------|-------------------|--------------------------|---------------------|---------------------|
| (1)     | 276,000           | 0.16                     | 247                  | 0.36                |
| (2)     | 600,000           | 0.27                     | 342                  | 0.36                |

Similar results were obtained using an ordinary master cylinder check valve as illustrated in Figure 3 soldered in the filler cap in place of the Bunsen type valve above described. The valve was placed so that pressure built up in the master cylinder forces the rubber valve lips 8 against the metal valve body 9 tendency to hold a slight pressure, while a vacuum collapses the cup lip 8, and hence is released immediately. Still another type of check valve which operates in the above manner is illustrated in Figure 4. It is composed of two rubber discs 10 and 14, positioned in the filler-plug 13 or on the meter container previously described, through which there is a hole and the other is attached to and seats against the first disc. Thus a check valve is formed, which tends to hold a slight pressure upon the reservoir 1 while releasing a vacuum.

Example 3.—Referring to Figure 7, the vent line on the drying container used in Example 1 is fitted with a Bunsen type valve as described in Example 2 and the assembly is fitted to the master cylinder reservoir. The Bunsen type valve reduces the passage of air over the drier to a minimum, thus prolonging the life of the drier and making it possible to use a smaller drying tube for the same period of use.

Although the foregoing description has shown tubular containers for the drying agents, the invention is not limited thereto, since it is obvious that many other containers for the drying agent will function equally as well in the practice of the invention. The fluid reservoir itself, if enlarged and provided with suitable retaining screens, may serve as the container when the drying agent is silica gel or other substance inert to actual fluid contact.

In combining a drying tube with a check valve to prevent both moisture ingress and breather of air, the check valve may be positioned between the atmosphere and the drying agent, or, if desired, between the drying agent and the reservoir. While several suitable drying agents have been named. It is apparent that many others also are adapted to prevent moisture entry into the reservoir. It is generally advisable to use a drying agent which is non-deliquescent and non-corrosive. For this reason, alumina or silica gel is the preferred drying agent.

While several types of check valves as above illustrated and described are suitable to prevent air breathing or pulsation through the vent line. It is apparent that any check valve positioned to permit a slight air pressure to build up in the reservoir while at the same time preventing a vacuum therein is well adapted for the purposes of this invention. The check valve used must, of course, be unable to hold such a pressure in the system that normal functioning of the brakes might be impeded. The check valve is designed merely to prevent air pulsation through the breather holes and not to permit the retention of any substantial pressure permanently upon the fluid reservoir.

While the invention has been particularly described with reference to preventing the absorption of water by high boiling brake fluids, in order that their boiling point be not reduced, it is nevertheless applicable to any hydraulically actuated system to prevent accumulation of moisture therein. There are many other uses for hydraulic brake type actuating systems such as to operate friction clutches, shifting mechanisms, traveling crane brakes, aircraft controls, and the like. Fluid couplings and fluid torque converters are also being used to transmit power on all types of moving vehicles. To insure satisfactory operation, the absorption of water by fluids used in such mechanisms should be prevented. The methods and means described in this invention are adaptable to prevent to a large extent the absorption of water by fluids used in such systems.

It is apparent that various changes may be made in the methods and means described without departing from the spirit and scope of the invention or sacrificing any of its advantages.

What is claimed is:

1. In a hydraulically-actuated system including a plurality of slave cylinders, a master cylinder, a hydraulic fluid reservoir communicating
with the master cylinder, air venting means for
the hydraulic fluid reservoir and conduit means
for transmitting hydraulic fluid pressure from
the master cylinder to the slave cylinders, the
combination therewith of a container holding a
drying agent, the container being in closed com-
munication with the hydraulic fluid reservoir air
venting means and being itself vented to the at-
mosphere at a point such that air entering the
hydraulic fluid reservoir must first pass over the
drying agent and be deprived of its water con-
tent.
2. The combination of claim 1 wherein the dry-
ing agent is selected from the group consisting
of activated alumina, silica gel, alumina gel, ac-
tivated carbon, calcium sulfate and calcium chlo-
ride.
3. In a hydraulic brake system including a plu-
rality of wheel cylinders, a master cylinder, a
hydraulic fluid reservoir communicating with the
master cylinder, air venting means for the fluid
reservoir, and conduit means for transmitting
fluid pressure from the master cylinder to the
wheel cylinders, the combination therewith of
means for retarding air escape from the hy-
draulic fluid reservoir and means for drying at-
mospheric air entering the hydraulic fluid reser-
voir, the said means for retarding air escape be-
ing adapted to prevent air breathing or pulsation
during brake application but not substantially to
affect normal compensation for volume changes,
including temperature- and seepage-induced vol-
ume changes, within the system.

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