HYDRAULICALLY CONTROLLED APPARATUS

FIG. 5.

FIG. 6.

Inventor
Francis H. Tennis

By
Attorney
HYDRAULLCALLY CONTROLLED APPARATUS

Francis H. Tennis, Milwaukee, Wis., assignor to Hydraulic Unit Specialties Co., Pewaukee, Wis., a corporation of Wisconsin

Filed Sept. 18, 1958, Ser. No. 761,799
5 6 Claims. (Cl. 137—621)

This invention relates to hydraulically controlled apparatus and has more particular reference to apparatus of the type having hydraulic means for effecting lifting and lowering of a heavy member on the apparatus during use thereof.

Excavating machines known as front end loaders are specific examples of apparatus of the type to which this invention pertains, but it will be understood that the apparatus can be of any wide variety wherein a load is lifted and lowered hydraulically.

Front end loaders are usually equipped with a source of motive power such as a gasoline or diesel engine, and the heavy member thereof which must be lifted and lowered during use of the machine comprises a boom structure pivoted at one end on the machine and tiltably carrying a digging bucket at its other end. The boom structure and the bucket carried thereby are operated by a hydraulic system which includes a reservoir for hydraulic fluid, a pump driven by the engine of the machine and supplied with fluid from the reservoir, a cylinder connected between the boom structure and the bucket for tilting the bucket to and from dumping position, and a pair of cylinders, usually referred to as the boom "cylinder," connected between the boom structure and the frame of the machine for effecting lifting and lowering of the boom structure. These cylinders are usually of the double acting type and their operation is governed by a manually operable control valve means on the machine.

Such a control valve ordinarily is provided with manually shiftable boom and bucket valve elements each normally occupying a neutral or "hold" position at which hydraulic fluid is trapped in both ends of the cylinder controlled thereby but shiftable in opposite directions to either of two operating positions at which the valve element directs pressure fluid into one end of its cylinder and directs to the reservoir the fluid exhausted from the other end of its cylinder.

In use, the boom structure of a front end loader is held in a lowered position by its cylinder, with the bucket thereon at ground level and ahead of the machine. Consequently, the bucket is caused to dig into and become filled with ground as a result of forward motion of the machine while the operator manipulates the control valve means to properly regulate the level of the boom structure.

The ground in the bucket may be discharged into a dump truck, for example, and this entails lifting of the bucket by its boom structure and tilting of the elevated bucket after the loader has run from the digging location to the dumping location. The boom structure is ordinarily held in its elevated position when the loader is returned to its digging location, and it is not lowered to begin the next digging cycle until the loader closely approaches or has arrived at the digging site.

For efficient operation of such front end loaders it is desirable to carry out such a working or digging cycle in the shortest possible time and particularly without delay due to the operation of its hydraulic cylinders. Actuation of the double acting boom cylinder, of course, consumes the greatest part of cylinder cycling time, and in the past an annoying aspect of the operation of the boom cylinder resulted from the fact that the descent of the boom structure was more or less hindered by its cylinder. For example, although aided in its descent by the force of gravity acting thereon, the descent of the boom structure was either slowed by the inability of the pump to supply sufficient pressure fluid into the upper end of the boom cylinder, through the control valve, or a more rapid descent of the boom structure created a void in the upper end of its cylinder. In the latter case, considerable time was lost after lowering of the boom structure due to the fact that its cylinders had to be refilled with fluid by the pump before controlled digging could be recommenced.

An obvious way to overcome such delays would be to increase the size and capacity of the hydraulic pump. However, such an expedient is impracticable not only because of the increased cost involved but also by reason of the fact that the power requirements of a sufficiently large pump could conceivably exceed those which could be supplied by the engine of the machine.

It is the purpose of this invention, therefore, to provide simple and inexpensive means for efficaciously achieving maximum cylinder cycling speed for the boom structures of front end loaders or for other hydraulically operated apparatus having a heavy member which must be lifted and lowered hydraulically during use.

More specifically it is an object of this invention to provide a hydraulic system especially suited for excavating and ground handling apparatus such as front end loaders and the like, which system features means for effecting communication between both ends of the hydraulic cylinder governing the boom structure of the apparatus, during descent of the boom structure, so as to enable the latter to be lowered to its digging position as quickly as possible, without danger of drawing voids in the cylinder.

In this respect it is a further object of this invention to provide a hydraulic system of the character described with a feed back valve which opens in response to the pressure of fluid exhausting from the lower end of the boom cylinder during descent of the boom to communicate the lower end of the cylinder with its upper end, thereby effecting exhaust of at least part of the fluid from the cylinder into its upper end whenever the pressure of the exhausting fluid achieves a predetermined value.

Another object of this invention resides in the provision of a hydraulic system for use with apparatus having a heavy member which must be lifted and lowered hydraulically and which moves beyond a position at which it opposes extension of the work performing element of its cylinder, and wherein said system is provided with means for effecting positive initial returning motion of the heavy member followed by unrestricted gravity descent of the member without opposition by its cylinder and without drawing a void therein.

With the above and other objects in view which will appear as the description proceeds, this invention resides in the novel construction, combination and arrangements of parts substantially as hereinafter described and more particularly defined by the appended claims, it being understood that such changes in the construction and details of the hereinafter claimed invention may be made as come within the scope of the claims.

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

The claims.
2,980,185

Figure 1 is a side elevational view of a front end loader incorporating this invention; Figure 2 is a diagrammatic view of the hydraulic system; Figure 3 is a longitudinal sectional view through the control valve means by which the boom cylinder (or cylinders) is operated, showing the valve element therefor in neutral position; Figure 4 is a cross sectional view taken on the plane of the line 4—4 in Figure 3; Figure 4a is a sectional view, on a reduced scale, taken through Figure 3 along the line 4a—4a; Figure 5 is a view similar to Figure 3 but showing the valve element shifted to an operating position effecting lowering of the boom structure; Figure 6 is a longitudinal sectional view similar to Figure 3 but illustrating a slightly modified form of the invention; and Figure 7 is a more or less diagrammatic elevational view of a dump truck incorporating this invention.

Referring now more particularly to the accompanying drawings, in which like reference characters have been applied to like parts throughout the several views, the numeral 10 generally designates a front end loader having a chassis 11 supported by pairs of front and rear wheels 12 and 13, respectively, having an engine (not shown) enclosed within a housing structure 14 over the rear wheels of the loader.

The boom structure 15 of the loader comprises a pair of elongated opposite arms, one at each side of the loader, having their rear ends pivotally mounted on the chassis as at 16 to swing about a common transverse axis located substantially midway between but above the level of the wheels 12—13. The arms of the boom structure extend forwardly and downwardly to a point ahead of the front wheels 12, and a bucket 17 is pivotally connected to their forward extremities, as at 18, for tilting motion between digging and discharging positions.

As shown in Figure 1, the bucket 17 is held in a lowered or digging position by the boom structure such that upon forward propulsions of the loader together with suitable regulation of the level of the boom structure, the bucket 17 is caused to swing about its pivot connection 18 and be raised to discharge its load. When the bucket 17 is to be lowered by the boom, the bucket 17 is caused to swing about its pivot connection 18 and be lowered to its fully opened position.

A double acting hydraulic cylinder 20 connected between the forward end portion of the boom structure and the bucket in the manner shown provides for tilting the bucket back and forth. The hydraulic cylinder 20 is pivotally mounted on the boom structure as at 21.

When pressure fluid is forced into the "lift" port 25 the lower end of the boom cylinder, the work performed at 25 is caused to be extended to apply an upward lifting force on the boom by which it is swung upwardly in a counterclockwise direction as seen in Figure 1. During such extension of the work, the fluid enters the "lift" port 25 and the "dump" port 26 in the lower end of the cylinder and is returned to the reservoir 27 of the hydraulic system of the loader.

The hydraulic system, of course, further includes a pump 28 driven by the engine of the loader, and a control valve means 29 by which the operator of the loader may operate the cylinders 20 and 21 either separately or simultaneously. With respect to the boom cylinder 21, the operator may selectively connect the outlet 30 of the pump with either of the ports 25—26 of the cylinder and to concomitantly connect the other of said ports with the reservoir.

The inlet 31 of the pump is at all times in communication with the reservoir, to be supplied with fluid therefrom through a supply duct 32. Thus it will be evident that both the raising and the lowering of the boom structure is effected by hydraulic power, under the control of the valve means 29.

The control valve means 29, shown in Figures 3, 4 and 5, is on the order of that shown and described in my copending application Serial No. 51,496, filed June 27, 1955, now Patent No. 2,873,762, issued February 17, 1959. It differs therefrom principally in that it would ordinarily be provided with two identical endwise slidable valve elements, such as the element 34, one for the bucket cylinder 20 and one for the boom cylinder 21. For the sake of clarity, however, only the valve element 34 which controls the operation of the boom cylinder has been shown.

The control valve means is normally mounted on the loader in the front portion of the operator's cockpit 35, and it comprises a body 36 having a bore 37 therein to endwise slidable receive the valve element 34. The bore 37 crosswise intersects a through passage generally designated 39 having one end communicating with an inlet port 40 in one side of the valve body and its opposite end communicating with an outlet port 41, likewise opening to one side of the body. As herein shown, the through passage is comprised of branches which intersect the bore 37 at adjacent but axially spaced locations thereof, and have communication with one another through a short section 42 of the bore 37. A duct 43 connects the outlet 30 of the pump with the inlet 40 of the valve body and another duct 44 connects the outlet 41 of the valve body with the reservoir 27.

The valve element 34 is formed with a central circumferential groove 45 which in the neutral or "hold" position of the valve element shown in Figures 3 and 4 spans the section 42 of its bore and affords substantially unrestricted communication of the through passage whereby all of the fluid entering the inlet 40 of the valve body from the pump flows substantially directly through the valve body and out of its outlet 41 for return to the reservoir.

At axially opposite sides of the through passage 39 the bore 37 is enlarged to provide pressure wells 47 and 48. The pressure well 47 is disposed intermediate the through passage and an enlargement 49 of the bore which provides a chamber that communicates with the motor "lift" port 50. The other pressure well 48 is located intermediate the through passage and another enlargement 51 of the bore which provides a chamber that communicates with the motor "lower" port 52. A duct 53 connects the motor "lift" port 50 with the "lift" port 25 at the bottom of the boom cylinder 21, and a duct 54 connects the motor "lower" port 52 with the "lower" port 26 in the upper end of the boom cylinder.

Also communicating with the inlet 40 of the valve body is a feeder passage 55 which, referring to Figures 4 and 4a, is shown as connecting with the righthand or inlet branch of the through passage 39 to be thereby communicated with an inlet chamber 56 in the valve body, into which the inlet 40 opens. The feeder passage 55 connects with the right portion 57 of a U-shaped bridging passage 58 through a port 59 controlled by a check valve 60. The U-shaped bridging passage 58 may be con-
sidered as constituting the terminal portion of the feeder passage, and it has opposite branches 61 and 62 which communicate with and terminate at the pressure wells 47 and 48, respectively.

In the natural or hold position of the valve element 34 shown in Figures 3 and 4, lands 63 and 64 of the valve element at opposite sides of its groove 46 respectively block communication between the pressure wells 47 and 48 and their adjacent motor port chambers 49 and 51. However, when the valve element is shifted to the right to a "lift" position, its land 63 enters the bore port 42 and blocks communication between the inlet and outlet branches of the through passage 39 but affords communication between the pressure wells 47 and the adjacent motor port chamber 49. Hence pressure fluid entering the inlet 40 of the valve body from the pump is diverted into the feeder passage 55 where it unseats the check valve 60 against the bias of a spring 65 acting thereon, and flows through the lefthand branch 61 of the bridging passage 58 into the pressure well 47 and through the valve bore into the motor port chamber 49, and out of the motor "lift" port 50 to the lower end of the boom cylinder 21 through the duct 53 and "lift" port 25 of the cylinder. This causes the work performing element 23 of the cylinder to be extended to effect upward swinging of the boom structure through another desired angle.

The boom structure may be held in any elevated position by returning the valve element 34 to its neutral position shown in Figures 3 and 4, for example to enable the loader to be maneuvered to a position alongside a dump truck or the like. Discharge of the load carried in the bucket thus elevated by the boom structure, of course, would be effected by extension of the work performing element of the bucket cylinder 20, as a consequence of shifting of its control valve element (not shown), to cause the bucket to be tilted in a clockwise direction about its pivotal connection with the boom arm (not shown). After the load in the bucket has been so discharged the bucket may be brought back to its normal position by shifting the valve element governing its cylinder 20 to its other operating position, and while the boom structure remains in its elevated position, the operator usually drives the loader back to the digging site before lowering the boom structure to place the bucket at ground level for the next digging cycle.

Lowering of the boom structure is effected by shifting the valve element 34 to the left, from its neutral position, to a "lower" position seen in Figure 5 at which the land 64 of the valve element blocks the through passage 39 and causes the pressure well 48 with the adjacent motor port chamber 51. When the valve element is so shifted, pressure fluid introduced into the inlet 40 of the valve body from the pump is diverted into the feeder passage 55 to unseat the check valve 60 and to flow through the branch 62 of the bridging passage into the pressure well 48, through the bore 37 into the motor port chamber 51, to issue from the motor "lower" port 52 from whence it is directed into the upper end of the boom cylinder through the duct 54 and the cylinder "lower" port 26. Pressure fluid flowing into the cylinder "lower" port 26 in the manner described applies retracting force to the work performing element of the cylinder to cause the boom structure to swing in a counterclockwise, or lowering direction. As in all front end loaders of the type herein concerned, gravity acts upon the heavy boom structure and the bucket carried thereby with a force that greatly assists lowering of the boom structure.

When the valve element 34 is shifted out of neutral to either of its operating positions described, fluid under pressure is directed into one end of the cylinder and the fluid discharged from the other end thereof is returned to the reservoir through suitable exhaust passages in the valve body. In the valve illustrated, the valve body is provided with exhaust passages 66 and 67, separate from the through passage and selectively communicable with the motor port chambers 49 and 51, respectively, by shifting of the valve element 34 to its operating positions. Both of these exhaust passages intersect the bore 37 for the valve element 34 with the exhaust passage 66 located outwardly adjacent to the motor port chamber 49, and the other passage 67 located outwardly adjacent to the motor port chamber 51.

Communication between the exhaust passages and their respective motor port chambers is controlled by lands 68 and 69 on the end portions of the valve element which, in the neutral position of the valve element, block communication between both motor port chambers and their exhaust passages.

When the valve element is shifted to the right to effect lifting of the boom structure in the manner described, the land 69 on the right hand end of the valve element is moved out of its position blocking communication between the motor port chamber 51 and its exhaust passage 67 to allow fluid discharging from the upper end of the boom cylinder 21 to flow via duct 54, the motor "lower" port 52 and its chamber 51 into the exhaust passage 67 then communicated therewith. The fluid thus exhausted into the passage 67 leaves the valve body through a discharge port 70 which is communicated in any suitable manner with the reservoir 27.

Similarly when the valve element 34 is shifted to the left to its "lower" position communicating the pressure well 48 with its adjacent motor port chamber 51 to effect lowering of the boom structure, communication is established between the motor port chamber 49 for the motor "lift" port and its exhaust passage 66 so that the fluid expelled from the cylinder "lift" port 25 flows back into the motor "lift" port 50, and through its chamber 49 into the exhaust passage 66. The passage 66 is communicated with the outlet 41 in the valve body through a small bore 71 in a plug 72 threaded into a wall portion 73 of the valve which normally separates the outlet 41 from the discharge passage 66. As will be brought out in greater detail shortly, the communication of the exhaust passage 66 with the outlet 41 of the valve body through the restriction afforded by the small hole 71 in the plug 72 is an important feature of this invention.

Attention is directed to the fact that the exhaust passage 66 for the motor "lift" port 50 extends around the wall portion 73 surrounding the outlet passage 41 and has a branch 74 extending inwardly toward the pressure well 48 but not communicating with the latter. The branch 74 of the exhaust passage 66 lies adjacent to a downward extending portion 75 of the motor port chamber 51 and is adapted to be communicated therewith through a short bore 76 having a valve seat 77 formed therein, facing away from the branch 74 of the exhaust passage. A plunger type valve 78 slidable in a slightly enlarged outwardly extending portion 79 of the bore 76 is urged inwardly by a spring 80 to a position normally engaging the valve seat, to thus close off communication between the chamber 51 and the exhaust passage 66. With this arrangement, the extension 75 of the motor port chamber cooperates with the bore 76 to provide a feed back passage normally closed by the valve 78, and since the inner end of the valve 78 is exposed to the branch 74 of the exhaust passage 66, the valve is at all times sensitive to the pressure obtaining in the exhaust passage 66. This feed back passage, when open, becomes part of the exhaust passage 66, and is thus independent of the through passage 39.

The provision of the spring pressed valve 78 which is sensitive and responsive to the pressure of fluid in the exhaust passage 66 is one of the most important features of the apparatus of this invention, for by reason thereof, considerable saving in cycling time for the boom cylinder is effected. While actualization of the valve element 34 in the direction to effect lowering of the boom structure initially imparts a positive hydraulic force to the work performing element of cylinder to start the boom struc-
ture traveling downwardly, gravity usually acts upon the boom structure with a force that tends to cause it to descend at a rate faster than hydraulic fluid can be supplied to the cylinder "lower" port 26 by the pump through the valve means. Consequently, descent of the boom structure heretofore was either inhibited by the inability of the pump to supply sufficient hydraulic fluid to the upper end of the boom cylinder, or else a more rapid gravity induced descent of the boom cylinder resulted. Such rapid retraction of the working element 23 of the boom cylinder that a void was created in the upper end of the cylinder.

In either event, delay was ordinarily experienced in the work cycle of the boom cylinder, for in one instance if no voids were created, the descent of the boom structure was limited to a rate depending solely upon the rate at which hydraulic fluid could be delivered into the upper end of its cylinder, and in the other instance if voids were created, the boom structure had to remain in its lowered position until its cylinder was refilled by the pump, before digging could be recommenced.

The provision of the spring pressed valve 78, however, has the effect of providing for connection of the cylinder "lift" port 25 with the cylinder "lower" port 26, through the control valve means when the boom structure is descending, so as to cause at least part of the fluid exhausting from the lower end of the cylinder to be directed back into its upper end to thus augment the flow of hydraulic fluid thereinto from the pump. Consequently, the boom structure is enabled to descend unimpeded, unhindered by the limited capacity of the pump, to assure the fastest possible cycling time for the boom cylinder.

This is made possible by reason of the fact that whenever the valve element 34 governing the boom cylinder "lift" port 25 is in the vertical position, the control valve means 29 is open and the exhaust port 86 is normally closed by the relief valve element 83.

The exhaust port 86, of course, is communicated in any suitable fashion with the reservoir. If desired, the feedback action may be taken into account through the exhaust passage 66 for the motor "lift" port whenever the boom structure is descending can be discharged to the reservoir through the outlet port 86, thereby assuring that the pressure of such exhausting fluid in the passage 66 will quickly build up to a predetermined value at which the spring loaded back valve 78 is seated to in effect communicate the opposite ends of the boom cylinder with one another in the manner described previously. In all other respects the control valve means 29 is the same as that described above.

One of the advantages of the hydraulic control system of this invention is that it may be used with excavating and ground handling apparatus of a type such as shown in Figure 7, which illustrates a dump truck having a body 90 which may be tilted about a pivot 91 at its lower rear from a horizontal transit position shown in solid lines to an elevated dumping position shown in construction lines, through an arc of more than 90°. Consequently, it will be seen that the body resists extension of the work performing element 23 of the hydraulic cylinder 21 for the body for the major part of lifting of the body, but that the body no longer opposes but in fact promotes such extension of the work performing element after the body has been swung past a vertical portion to an extreme discharging position seen in construction lines in Figure 7.

After the load of the body has been dumped, it cannot return to its transit position by gravity. Hydraulic fluid under pressure must be forced into the upper end of the cylinder 21 by proper actuation of the valve element governing the same to effect possible return motion of the body through retraction of the work performing element of the cylinder. Thus, the body must be returned at least an extent such that it is carried past a vertical position to a location at which gravity may act thereupon and speed the descent of the body.

When gravity begins to act upon the body it causes it to descend at a rate faster than hydraulic fluid can be fed into the upper end of its cylinder from the pump, and the descent of the body would either be hindered by the limited capacity of the pump, or it would result in creating a void at the upper end of the cylinder. The hydraulic control system of this invention, however, due to the incorporation of the pressure responsive feedback valve 78 therein eliminates any possibility of such voids being created in the upper end of the cylinder during descent of the body and allows the body to descend at the fastest possible rate until it closely approaches its transit position. Thereupon, the valve element governing the cylinder 21 can be actuated to slow and stop the descent of the body.

It will be understood, of course, that the hydraulic system of this invention would be provided with some
sort of cushioning means, as for instance an accumulator, in order to enable the descent of either the boom structure or the body of a dump truck to be suddenly stopped when it reaches the desired lowered position without danger to the components of the system.

From the foregoing description together with the accompanying drawings, it will be apparent to those skilled in the art that this invention greatly improves the operation of and speeds the cylinder cycling time in apparatus having a heavy member which must be raised and lowered hydraulically during use of the apparatus.

What is claimed as my invention is:

1. A hydraulic control valve unit, comprising: a body having a bore, inlet and outlet means, a through passage connecting the inlet and outlet means and having an intermediate portion intersecting the bore, a pair of motor ports, a high pressure passage for each motor port, said high pressure passages communicating the motor ports with the bore at zones spaced from one another and from the junction of the through passage with the bore, and exhaust passage means which is separate from the through passage but communicated with said outlet means and communicable with each high pressure motor port passage through the bore; a valve element shiftable back and forth in the bore from a neutral position to either of two operating positions, said valve element being adapted to clear the through passage in said neutral position thereof and thereby provide for free flow of fluid from the inlet to the outlet means, but being adapted to block the through passage at its junction with the bore in either operating position thereof; said body having feeder passage means therein communicated with the inlet and having a terminal portion joining with the bore, and into which feeder passage means fluid entering the inlet is diverted by the valve element in either operating position thereof for travel to the bore, the junctions of the through passage and said terminal portion of the feeder passage means with the bore being independent and spaced apart axially of the bore; the valve element being adapted to selectively communicate either high pressure motor port passage with said terminal portion of the feeder passage means and the other high pressure motor port passage with the exhaust passage means upon shifting of the valve element to said operating positions thereof; said body having means providing a feed back passage therein which is entirely independent of the through passage and which is adapted to connect the high pressure motor port passages with one another; and a pressure sensitive valve in said feed back passage normally closing the same, said valve being adapted to open in an operating position of the valve element to communicate the high pressure motor port passage then in communication with the feeder passage means with that high pressure motor port passage which is then in communication with the exhaust passage means, in response to a drop in fluid pressure at said first designated high pressure motor port passage to a valve below that obtaining at said second designated high pressure motor port passage.

2. The hydraulic control valve unit of claim 1, further characterized by: the fact that said exhaust passage means is comprised of a pair of branches, one for each of said high pressure motor port passages, the branch for said first designated high pressure motor port passage leading unrestrictedly to said outlet means; and the branch for said second designated high pressure motor port passage having means therein to meteringly restrict its communication with the outlet means.

3. The hydraulic control valve unit of claim 2, wherein said restricting means is located adjacent to the outlet end of said branch of the exhaust passage means containing the same.

4. The hydraulic control valve unit of claim 1, further characterized by the provision of normally closed check valve means in the body serving said motor ports, said check valve means being located in the path of fluid diverted through the feeder passage means to the bore in said operating positions of the valve element so as not to interfere with the bypass of fluid from said second designated high pressure motor port passage to said first designated high pressure motor port passage in said designated operating position of the valve element.

5. The hydraulic control valve unit of claim 2, further characterized by the provision of: separate but adjacent inlet and exhaust chambers in the body, the body inlet opening into said inlet chamber and the exhaust chamber being communicable with said second designated high pressure motor port passage through the exhaust branch therefor, and said exhaust chamber having an exhaust port which opens to the exterior of the body at one side of the body inlet and forms part of said outlet means; and normally closed relief valve mechanism in the body, having an inlet portion disposed in said inlet chamber, and an outlet portion in said exhaust chamber.

6. The hydraulic control valve unit of claim 5, further characterized by the fact that said outlet means also includes a second exhaust port in the body, at the other side of the body inlet, and communicable with said first designated high pressure motor port passage through the exhaust branch therefor.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Date</th>
<th>Inventor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,267,284</td>
<td>Dec. 23, 1941</td>
<td>Livers</td>
</tr>
<tr>
<td>2,359,802</td>
<td>Oct. 10, 1944</td>
<td>Stephens</td>
</tr>
<tr>
<td>2,367,682</td>
<td>Jan. 31, 1945</td>
<td>Kehle</td>
</tr>
<tr>
<td>2,543,989</td>
<td>Mar. 6, 1951</td>
<td>Rockwell</td>
</tr>
<tr>
<td>2,581,430</td>
<td>Jan. 8, 1952</td>
<td>Mork et al.</td>
</tr>
<tr>
<td>2,590,454</td>
<td>Mar. 25, 1952</td>
<td>Pilch</td>
</tr>
</tbody>
</table>