March 31, 1942. R. K. BERNHARD 2,277,813

MATERIAL TESTING APPARATUS

Filed Dec. 18, 1937 2 Sheets-Sheet 1

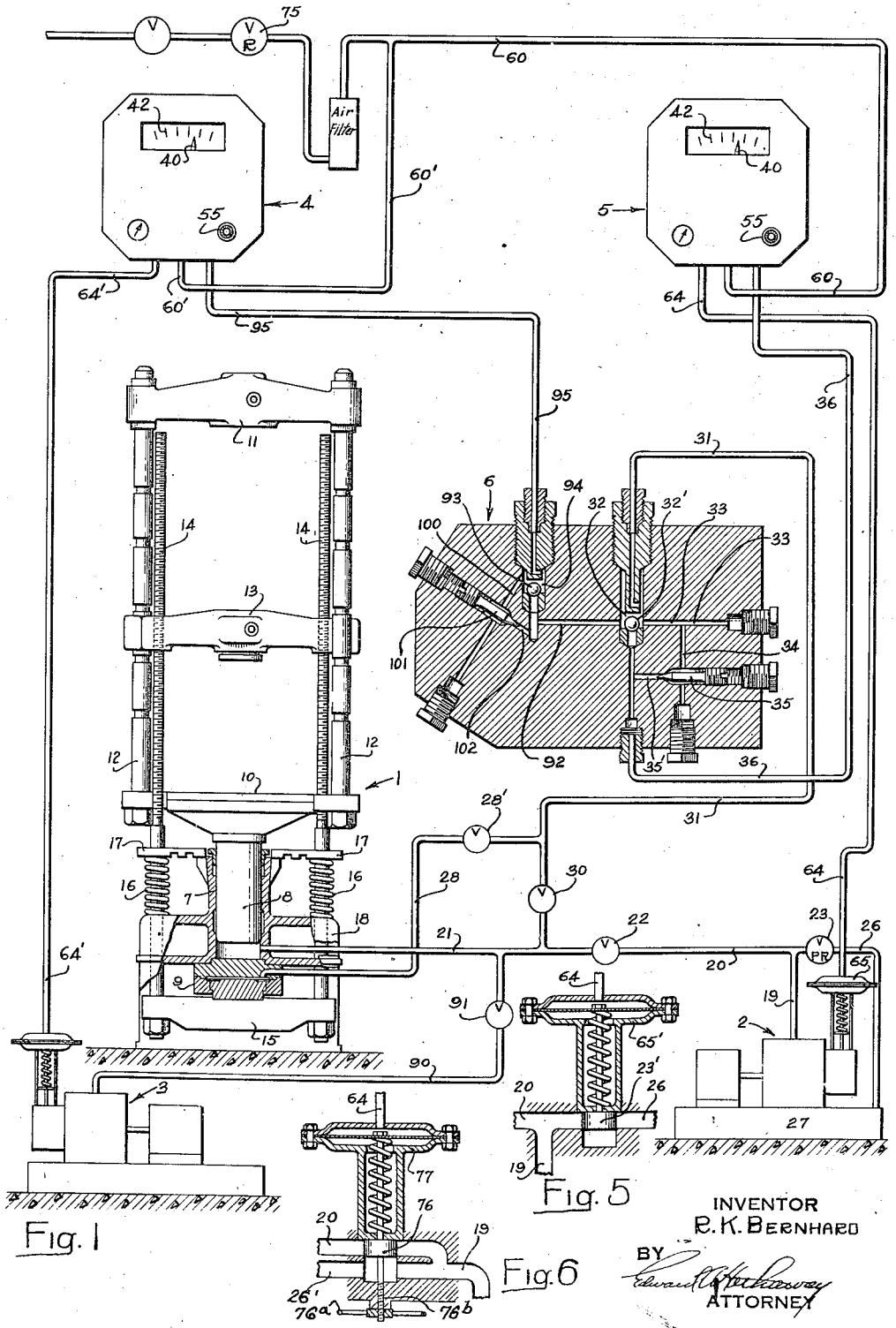


Fig. 1

Fig. 5

Fig. 6

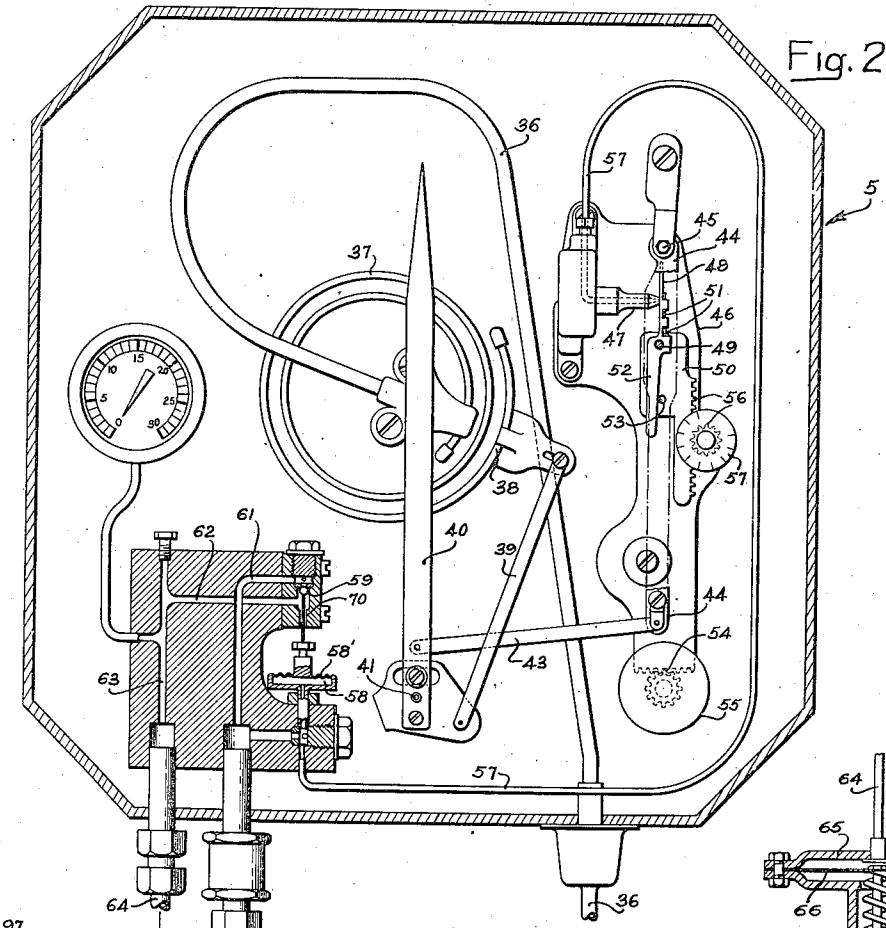
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MATERIAL TESTING APPARATUS

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Fig. 2



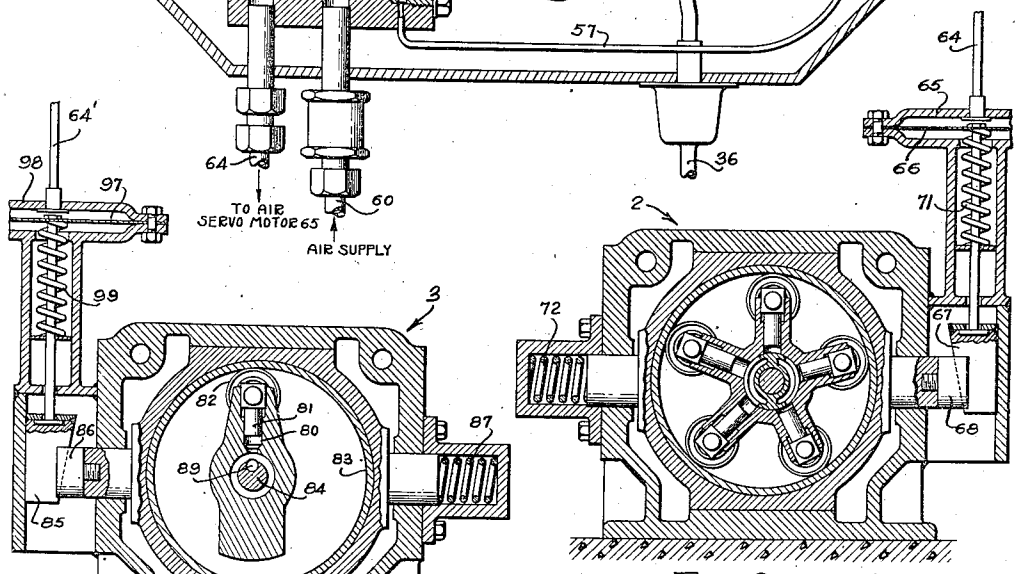


Fig. 4

Fig. 3

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UNITED STATES PATENT OFFICE

2,277,813

MATERIALS TESTING APPARATUS

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Application December 18, 1937, Serial No. 180,491

12 Claims. (Cl. 265—14)

This invention relates generally to materials testing apparatus and more particularly to apparatus for subjecting a test specimen to a pulsating load between predetermined maximum and minimum loads.

Various arrangements have been heretofore suggested and used for subjecting a specimen to pulsating loads, but such prior arrangements have been deficient in various respects including the inability to subject the specimen to a pulsating load along a true sine curve. Other deficiencies have been the inability to control the pressure limits with a high degree of accuracy and sensitivity regardless of whether the pressure limits were relatively low or high or of small or large differential.

It is an object of my invention to provide an improved apparatus and control system, together with improved pressure responsive and pressure filtering means, whereby all of the foregoing deficiencies may be substantially if not wholly overcome while at the same time obtaining a high degree of accuracy, sensitivity, stability and ease and rapidity of adjustment of the pressure limits as well as widely varying the pressure differential between such limits.

It is a further object of my invention to accomplish the foregoing desirable results in an apparatus which, considering the niceties of control and responsiveness necessary, is relatively economical in manufacture, operation and maintenance. In one specific aspect of my invention I have provided a main pump for producing a predetermined minimum constant pressure and a pulsating pump for producing a pulsating pressure having a predetermined maximum pressure. These pumps are respectively controlled by minimum and maximum pressure controllers.

Other objects and advantages will be more apparent to those skilled in the art from the following description of the accompanying drawings in which:

Fig. 1 is a diagrammatic outline of the elements embodied in my improved apparatus, parts of which are shown in section to disclose the mechanical details thereof;

Fig. 2 is an enlarged front elevation of one of the controllers, parts of which are broken away to show details of construction;

Fig. 3 is an enlarged sectional view of the main pump for establishing a constant pressure;

Fig. 4 is an enlarged sectional view of the pulsator pump;

Fig. 5 is a fragmentary diagrammatic view of a modified form of means for controlling the rate of flow from the main pumping unit to the hydraulic load producing apparatus;

Fig. 6 is another modification of means for controlling the rate of flow from the main pumping unit.

In the particular form of the invention, such as is disclosed herein merely for the purpose of illustrating one specific form among possible others that the invention might take in practice, I have shown a hydraulic loading apparatus such as a materials testing machine 1 in combination with a motor-driven main pump 2 preferably of the variable displacement Hele-Shaw type as shown in Patent No. 1,152,729, together with a motor-driven variable displacement pulsator pump 3, a combined maximum pressure indicator and controller 4, a combined minimum pressure indicator and controller 5, and a maximum and minimum pressure control or filtering valve mechanism 6. The testing machine disclosed herein is of the well-known Emery type disclosed in Emery Patent No. 1,848,468 having generally a loading cylinder 7 and ram 8 and a hydraulic support 9. The ram 8 is formed as a fixed part of a loading frame comprising a lower platen 10, an upper crosshead 11 and side rods 12 whereby this whole frame moves as an integral unit with ram 8 during loading or unloading of a specimen. A sensitive frame has an intermediate crosshead 13 adjustably supported on threaded rods 14 which in turn are secured to a lower crosshead 15 while usual preloading springs 16, interposed between usual flexible stay plates 17 and a cylinder base 18, urge the sensitive frame upwardly to bring lower crosshead 15 into contact with a movable portion of hydraulic support 9 to preload the same. The ends of the stay plates 17 are secured to cylinder 7 and to rods 14 thereby to laterally guide and support the sensitive frame during its minute movements. As shown the hydraulic support 9 is seated against and forms the head of cylinder 7. The pumps broadly comprise hydraulic means for subjecting the loading apparatus to a pulsating load while the controllers 4 and 5 are broadly pressure responsive means.

The main pumping unit 2 normally supplies fluid under a constant pressure to testing machine cylinder 7 beneath ram 8 through pipes 19, 20 and 21 in which a normally open stop valve 22 is disposed. A pressure relief valve 23 is adapted upon occurrence of an abnormally high pressure in pump 2 to bypass fluid therefrom through a drain pipe 26 to an oil sump 27. To determine the load upon the specimen, a pipe 28 normally connects the fluid space of the hydraulic support with a pressure gauge as shown in said Emery patent. While my invention is herein applied to the foregoing Emery type of machine to show the applicability thereto, yet it will be understood that my invention is equally applicable to simple ram and cylinder types of testing machines wherein the load on a specimen is determined directly by the pressure in the main cylinder, this being illustrated herein by a piping system having suitable valves that may be opened or

closed in order to determine load pressures directly in the main cylinder 7.

The structure of the remaining control elements together with their cooperative relation and the results obtained thereby will be more readily followed from the following description of the mode of operation thereof.

For purposes of simplicity, the operation will be described first for a simple ram and cylinder type of machine which is accomplished by closing a valve 28', Fig. 1. Main pump unit 2 is first started whereupon it supplies hydraulic pressure fluid through pipes 19, 20 and 21 to the main loading cylinder 7 and also past a normally open valve 30 to an inlet pipe 31, thence through a ball check chamber 32 to passages 33 and 34 and past an adjustable needle valve 35 for controlling a by-pass passage 35'. This by-pass is connected to a minimum pressure outlet pipe 36 which leads to the minimum pressure indicator and controller 5, Figs. 1 and 2. The controller 5, per se, is well known and does not form a part of the invention except as an element of my improved combination. The controller consists of pipe 36 connected, as shown in Fig. 2, to a Bourdon tube 37 whereby upon increase of pump pressure the Bourdon tube expands to cause its free end 38 to move a pivotally connected link 39 downwardly, thereby swinging an indicating pointer 40 to the right about a pivot 41. The indicating pointer as shown in Fig. 1 moves over a dial 42 suitably graduated for pressure readings. Also during movement of pointer 40 a pivotally connected link 43, Fig. 2, moves an arm 44 about a stationary pivot 45. This pivot 45 also pivotally supports an adjustable frame 46 which carries both an air jet 47 and a jet baffle 48. The means for carrying the baffle by frame 46 consists in pivotally supporting the baffle as at 49 upon a vertically adjustable plate 50 which is suitably guided and supported upon the frame 46. A spring 51 biases baffle 48 in a counterclockwise direction until a finger 52, depending from and forming a part of the baffle, engages a pin 53 which is carried by arm 44 and projects inwardly into the path of finger 52. Link 44 overlies the baffle and arm 52. To adjust the predetermined pressure limit which the controller is to maintain, the lower end of pivotal frame 46 may be swung laterally in either direction through a rack and pinion 54 operated by a suitable knob 55 located on the outside of the instrument. Lateral movement of frame 46 causes baffle 48 to be initially positioned either closer to or further from jet 47, thereby adjusting the pressure limit in a manner to be presently described. To adjust the sensitivity of the action of the baffle 48 in response to a given movement of arm 44, plate 50 may be adjusted vertically in either direction by a rack and pinion 56 operated from a knob 57. Vertical movement of plate 50 will carry pivot 49 therewith and accordingly move baffle 48 and finger 52. Stop pin 53, by reason of being carried by link 44, will not be moved upon vertical adjustment of plate 50.

As the pressure of pump 2 increases, arm 44 and pin 53 are moved to the right about pivot 45 thereby allowing spring 51 to move finger 52 and baffle 48 in a counterclockwise direction about the normally stationary pivot 49. Such counterclockwise movement causes baffle 48 to move toward jet 47 to increasingly restrict air flow therefrom. During this baffle movement finger 52 will continuously bear against pin 53 so that the movement of arm 44 controls the extent of movement of the baffle. However, if the movement of arm 44 should be carried so far that the baffle actually engages the jet structure, then any further movement of arm 44 to the right will simply cause pin 53 to move away from finger 52 without any additional force being exerted on the baffle except the very slight force of spring 51. The aforesaid increasing restriction of the jet causes an increase of air pressure in a pipe 57 in a manner that is well known in the air relay art. Pipe 57 is connected to a diaphragm chamber 58 whose diaphragm 58' is connected to a ball valve 59. Said increase in pressure moves ball valve 59 upwardly toward its valve seat, thereby to wholly or partially shut off flow of pressure air from a supply pipe 60 in which the pressure is maintained substantially constant by flowing from a suitable source through a pressure reducing valve 75. Normally, the supply of air would flow through passage 61 past valve 59 and into passages 62 and 63 and thence through a pipe 64 to an air operated servo-motor 65, Figs. 1 and 3, thereby causing a diaphragm 66, Fig. 3, to adjust or hold pumping unit 2 away from its neutral position through a wedge cam 67 and a follower shaft 68. However, when the supply of air past valve 59 is increasingly restricted as aforesaid by an increasing pressure in Bourdon tube 37 and in diaphragm chamber 58, then fluid in passages 62 and 63 as well as in servo-motor 65 will be vented through a clearance 70 at a faster rate than the rate at which source fluid flows from passage 61 past valve 59. This will result in a drop of pressure in the servo-motor so that a spring 71, Fig. 3, will move wedge 67 upwardly to allow a spring 72 to adjust pump 2 toward the right, thereby reducing the displacement thereof. When the pump pressure reaches a predetermined value, referred to herein as the "predetermined minimum pressure," the Bourdon tube will have caused jet 47 and valve 59, Fig. 2, to be completely or sufficiently closed so that the pump is in its neutral position.

With the predetermined minimum pressure now established, pulsator pump 3, Fig. 1, can be operated. Various types of pulsators may be employed for producing pressure fluctuations along a sine curve although in order to take advantage of and obtain the complete sine curve action, it is necessary to use such a pulsator in a cooperating control system such as disclosed herein. For purposes of illustration the pulsator pump shown herein is specifically of the type described in the application of H. J. Ruch, Serial No. 171,765, filed October 29, 1937, now Patent No. 2,194,914. Hence it need be only briefly described as comprising a rotating cylinder 80 carrying a piston 81 which is reciprocated by a follower roller 82 running upon a circular trackway 83. This trackway can be adjusted so that its center coincides with the axis of rotation of cylinder 80 about a shaft 84, thereby creating a neutral or non-pumping position of the pump, or its center may be variably shifted laterally to the right of shaft 84 to provide an eccentric relation to effect any desired degree of pulsator action. The eccentric adjustment of the trackway 83 is specifically accomplished either by downward movement of a cam wedge 85 acting on a follower 86 thereby moving the pump to the right away from its neutral position, or by a spring 87 adapted to move the pump to the left to decrease its eccentricity upon upward movement of cam 85 by a spring 99. The pulsator cylinder 80 is in constant open communication with the testing

machine loading system 7 and 8 through a passage 89, a pipe 90, Fig. 1, and pipe 21. A stop valve 91 may be employed to disconnect the pulsator apparatus whenever desired. To adjust the pulsator pump to give a predetermined maximum pressure, pipe 90 is connected to the maximum pressure indicator and controller 4, Fig. 1, through valve 30, pipe 31, chamber 32 and a passage 92 from which fluid flows upwardly to raise a check valve 93 and thence flows through a valve chamber 94 to a maximum pressure outlet pipe 95. The pipe 95 is connected to a Bourdon tube in controller 4 in the same manner that pipe 36, Fig. 2, is connected with Bourdon tube 37. The controller 4 is identical in construction and operation as that shown in Fig. 2 and hence it will suffice to refer to Fig. 2 in describing the manner in which the maximum pressure is controlled.

Assuming that the pulsator is not adjusted to produce a piston displacement which will give the desired maximum pressure, then the Bourdon tube in controller 4 will not be sufficiently expanded to restrict flow from the air jet and accordingly the air pressure supplied through pipe 60' (corresponding to pipe 60 of Fig. 2) will communicate freely with a servo-motor pipe 64' (corresponding to pipe 64 of Fig. 2). This air pressure in pipe 64' will move a diaphragm 97 of a servo-motor 96 downwardly against the action of a spring 99, thereby to cause wedge 85 to move follower 86 to the right with consequent increase in eccentricity of track 83 and displacement of fluid from the pulsator. The eccentricity will continue to increase with an accompanying increase of maximum pressure during each pulsation, until the desired pressure is obtained. However, as the pressure builds up it is transmitted through valve 30, pipe 31, chamber 32, passage 92 and chamber 94 to pipe 95, thereby expanding the Bourdon tube in controller 4 so as to restrict flow of fluid through the air jet supply pipe 60' with consequent restriction of air flow through pipe 64'. When the desired pressure is reached, the relation between the baffle and jet will be such as to hold a valve (corresponding to 59, Fig. 2) in a position whereby the servo-motor pressure in pipe 64' will be constant. Such constant pressure will allow diaphragm 97 to remain in a fixed position and accordingly the pump will be held in an adjusted position so that its eccentricity will be just sufficient to create the desired maximum pressure at the end of each stroke of piston 81. The end of the stroke is considered to be at the radially inner end of pulsator cylinder 80. The receding or outward movement of pulsator piston 81 allows the loading pressure to drop down to the minimum established by pump 2. If for any reason, the maximum pressure should fall below the desired predetermined value, the Bourdon tube in controller 4 will contract thereby moving the baffle away from its jet so as to allow the valve (corresponding to valve 59 of Fig. 2) to increase flow of fluid to pipe 64' thereby increasing the stroke of the pulsator piston. When the desired maximum pressure is reestablished, the Bourdon tube will have expanded to reestablish the stabilized relation between the jet and baffle. If for any reason the pulsator should produce a pressure overshooting the predetermined maximum, the Bourdon tube in controller 4 will have expanded so as to move the baffle nearer to the jet with consequent increased restriction of air flow therethrough resulting in the air relay (corresponding to 58, 58' and 59) restricting flow of air from supply pipe 60' to servo-motor pipe 64'. As a result the pressure acting on top of diaphragm 97, Fig. 4, will drop slightly whereupon spring 99 will move cam 85 upwardly to permit spring 87 to reduce the eccentricity of trackway 83 and the displacement of the pulsator piston with a consequent reduction in the maximum pressure to the desired value.

Maximum and minimum pressure control valve or filtering mechanism

Inasmuch as the minimum pressure controller 5 and the maximum pressure controller 4 are each subjected to the pressure variations caused by the pumping units 2 and 3 as well as being commonly connected to the same source, such as the pumps, through the same inlet pipe 31, the control valve or pressure filter mechanism 6 is so arranged as to permit the controller 5 to be responsive only to minimum pressures and the controller 4 responsive to only maximum pressures. For example, minimum pressure fluid cannot flow past check valve 32' to minimum pressure outlet pipe 36 but can only flow thereto through passages 33, 34 and past a restricted orifice, controlled by needle valve 35, to passage 35'. Hence so long as the pressure in pipe 31 is below the predetermined minimum value, pump 2 will supply fluid that flows past needle valve 35 to pipe 36 and to the Bourdon tube in controller 5. If for any reason the pressure in pipe 36 and the Bourdon tube 37 should increase slightly beyond the predetermined minimum, the main pump 2 will be moved to its neutral position as previously described. However, the system has a certain small amount of inherent leakage with the result that pressure in pipe 31 will gradually drop, thereby allowing the slightly excess pressure in pipe 36 to raise check valve 32' and establish the same pressure in pipe 36 as exists in pipe 31. When the pressure in pipes 31 and 36 has fallen slightly below the predetermined minimum, the Bourdon tube 37 will operate the jet and baffle 47 and 48 to adjust pump 2 so that it delivers a small amount of liquid to the loading system. Consequently the pressure will again flow through pipe 31 and past needle valve 35 to Bourdon tube 37, but this time the pressure in pipe 36 will not overshoot the predetermined minimum to the same extent as at the beginning of the pumping operation. The foregoing cycle will continue until the desired pressure is reached and stabilized. The restricted orifice controlled by needle valve 35 is, of course, a factor in stabilizing the operation because a momentary rise in pumping pressure above the desired minimum will be retarded in passing needle valve 35 and consequently the controller 5 has a high degree of stability in controlling the operation of pump 2.

The maximum pressure is controlled in the reverse manner to that for controlling the minimum pressure just described. For instance, the fluid from pulsator 3 flows freely through pipe 31, chamber 32 and passage 92 to raise check valve 93 and thence flows through pipe 95 to the Bourdon tube in controller 4. As the pressure of this fluid momentarily decreases during its series of pulsations, the pressure fluid which accumulates in pipe 95 will act downwardly on top of ball check 93 to close communication between chamber 94 and passage 92. So long as the pressure in pipe 95 is below the predetermined maximum, the controller 4 will cause increas-

ing adjustment of the pulsator 3 until the desired pressure is reached, but if the maximum pressure in pipe 95 should for any reason exceed the desired predetermined value, the Bourdon tube in controller 4 will adjust the jet-baffle mechanism thereof so that the pulsator 3 will reduce its displacement and pressure. The inherent lag of the various operating and control mechanisms may cause the pulsator to be momentarily adjusted to a point slightly below that which would give the necessary degree of displacement for maintaining maximum pressure. This drop of the maximum pressure will be relatively slight but will nevertheless be sufficient to permit any excess pressure in pipe 95 to equalize with the maximum pressure in passage 92. This equalization is accompanied by fluid flowing rearwardly from pipe 95 through a passage 100 past an adjustable needle valve 101 and passage 102 to the open pump passage 92. The reduced displacement of the pulsator and consequent reduction of pressure in pipe 95 will allow the jet-baffle mechanism of controller 4 to increase the displacement of the pulsator. This cycle of operations of first overshooting and then undershooting will very quickly become stabilized at substantially the maximum pressure. The restricted orifice controlled by needle valve 101 is a factor in stabilizing the operation of the controller 4 because upon occurrence of a momentary drop of pressure in passage 92, reverse flow from pipe 95 to passage 102 will be materially retarded by the restricted adjustment of needle valve 101. Hence before sufficient fluid can flow reversely past valve 101, the next wave of increasing pressure will occur so that, if necessary, ball check 93 will be lifted by the increasing pressure so as to increase the pressure in line 95 until the pressure therein is equal to the pressure in passage 92. This mode of operation is similar to that for the minimum pressure needle valve 35 which, of course, functions in the reverse manner as heretofore explained.

In the operations so far described it has been considered that the testing machine was operating as a simple ram and cylinder type wherein the cylinder pressure was taken as representative of the load on the specimen. This required opening of valve 30 and closing of valve 28' to disconnect the hydraulic support 9. However, if the independent weighing action of support 9 is to be employed, then valve 28' is opened and valve 30 closed. The pumps are still controlled in accordance with the maximum and minimum load pressures because these pressures are now transmitted from support 9 to valve 6. All other operations remain the same as before.

From the disclosure herein it is seen that two pumping mechanisms are provided one capable of producing only a predetermined minimum value and the other being capable of producing a pulsating maximum pressure together with a pressure controlling and responsive system that insures ease in adjustment and accuracy and sensitivity in operation. The pressure selector control mechanism functions in the nature of a filter for segregating the maximum and minimum pressures from each other. In the specific embodiment of the invention, each of the pumping mechanisms is adjusted by controllers which are respectively responsive only to maximum and minimum pressures, the adjustment of the pumps being such that the pressure pulsations are along a true sine curve regardless of what the maximum or minimum load values may be. This true sine curve is accomplished by reason of each pump being so adjusted or operated that they respectively independently produce only one pressure limit. In certain prior art pulsating and pumping arrangements, a relief valve is required in the system for cooperation with the pulsator in order to establish the maximum pressure limit, but this has the objectional feature that a true sine curve is not obtained because the relief valve functions to discharge pressure in excess of the desired maximum. This is equivalent to creating flat pressure lines across the top of the sine curve instead of a smooth continuous true sine such as is insured in the present combination. Furthermore, it is not necessary in my present combination, as is the case with the above prior art arrangement, to have a continuous rate of discharge from the main pumping unit 2 after its predetermined minimum value is established. This is because pump 2 is either returned to its neutral position or the discharge is otherwise controlled so as to in effect disconnect the pump from the loading system except for such minor leakage as may occasionally occur.

For example, if desired, pump 2 may be of the continuously operating constant displacement type. In this case, as diagrammatically shown in Fig. 5, the predetermined minimum pressure is established by automatically controlling a valve 23' by a servo-motor 65' which corresponds in every respect to servo-motor 65. The valve is located in the drain pipe 26 so that when the predetermined pressure is reached, valve 23' is opened to by-pass fluid from the pump through drain pipe 26 and when the pressure falls below said predetermined value, valve 23' moves toward its closed position to restrict or close pipe 26. A further arrangement as diagrammatically shown in Fig. 6, equivalent to stopping pump 2 or disconnecting the same from the loading system, is to insert in pipe 20 a stop valve 76 operated by a servo-motor 77. This servo-motor is connected to pipe 64 whereby when the predetermined minimum pressure is reached the valve 76 closes pipe 20 and by-passes fluid from the pump to a drain 26'. When the pressure drops below said predetermined minimum, the stop valve 76 opens to connect pipe 19 with pipe 20 and at the same time close the discharge through drain 26'. If desired, the valve 76 could be manually operated by adjusting a usual handwheel 76a and threaded valve stem 76b, the operator observing the pressure indication of pointer 40 of controller 5, Fig. 1. After the minimum pressure is obtained, adjustment of any of the stop valves 76 or valve 23' or the adjustment of the variable displacement pump 2 by the wedge 67 is merely for the purpose of supplying make-up fluid to take care of the leakage if such should occur. Broadly the pump and valve adjusting mechanisms comprise means for controlling or varying the rate of fluid flow to the load producing apparatus.

It will of course be understood that various changes in details of construction and arrangement of parts may be made by those skilled in the art without departing from the spirit of the invention as set forth in the appended claims.

I claim:

1. In combination, a hydraulic loading apparatus, hydraulic means for subjecting said loading apparatus to a pulsating load along a true sine curve extending continuously and uninterruptedly through a complete cycle, and means for varia-

bly controlling the maximum and minimum limits of the hydraulic pressure produced by said hydraulic means while maintaining said continuous and uninterrupted curve through all variations of load limits.

2. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load including a pump for producing a constant fluid pressure and a pulsator pump for producing a pulsating pressure along a true sine curve extending continuously and uninterruptedly through a complete cycle, and means for controlling one of said pumps in accordance with a predetermined maximum pressure and for controlling the other of said pumps in accordance with a predetermined minimum pressure while maintaining said continuous and uninterrupted curve through all variations of load limits.

3. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load between predetermined maximum and minimum pressure limits including a pump for producing a substantially constant pressure and a pulsator pump for producing a pulsating pressure along a true sine curve extending continuously and uninterruptedly through a complete cycle, pressure responsive means for controlling one of said pumps so as to produce said predetermined minimum pressure while the pressure is maintained along said continuous and uninterrupted curve, and pressure responsive means for controlling the other of said pumps to produce said predetermined maximum pressure while the pressure is maintained along said continuous and uninterrupted curve.

4. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load including a pump for producing a substantially constant pressure and a pulsating pump for producing a pulsating pressure along a true sine curve extending continuously and uninterruptedly through a complete cycle, a plurality of pressure responsive means respectively controlling said pumps in accordance with predetermined maximum and minimum pressure limits while maintaining the pressure along said continuous and uninterrupted curve, and means operative to transmit high pressure to one of said responsive means and to transmit low pressure to the other responsive means.

5. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load between predetermined maximum and minimum limits, and means for controlling said hydraulic means so as to produce said pressure limits including a pressure filtering mechanism operative to transmit maximum and minimum load pressures separately from each other.

6. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load between predetermined maximum and minimum limits, and means for controlling said hydraulic means so as to produce said pressure limits including a pressure filtering means having maximum and minimum pressure outlets supplied from a common pressure fluid source which is subjected to all pressure fluctuations between said pressure limits and means for conducting only the maximum and minimum limits of pressures to said outlets.

7. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load between predetermined maximum and minimum limits, and means for controlling said hydraulic means so as to produce said pressure limits including a pressure filtering means having maximum and minimum pressure outlets supplied from a common source of pressure fluid, a check valve and restricted by-pass around the same associated with one of said outlets to allow free flow of fluid thereto but restricted flow therefrom and another check valve and restricted by-pass around the same associated with the other of said outlets to allow restricted flow of fluid thereto but free flow therefrom, whereby the maximum and minimum pressures of said common source are adapted to be segregated.

8. The combination set forth in claim 7 further characterized in that said by-passes are provided with means for varying the rate of by-pass action around the check valves.

9. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load, and means for controlling said hydraulic means so as to maintain said pulsating load between predetermined maximum and minimum limits, said control means including means for varying the rate of fluid flow from the hydraulic means to said load producing apparatus and an air jet and baffle for controlling said rate of flow means.

10. The combination set forth in claim 3 further characterized in that each of said pressure responsive means includes a hydraulically operated Bourdon tube connected to the hydraulic means and an air jet and baffle controlled by said Bourdon tube, and means controlled by said air jets and baffles for controlling said hydraulically pumping means.

11. In combination, a hydraulic load producing apparatus, hydraulic means for subjecting said apparatus to a pulsating load between predetermined maximum and minimum pressure limits including a pump for producing a substantially constant pressure and a pulsator pump for producing a pulsating pressure, pressure responsive means for controlling one of said pumps so as to produce said predetermined minimum pressure, and pressure responsive means for controlling the other of said pumps to produce said predetermined maximum pressure; each of said pressure responsive means comprising a hydraulically operated Bourdon tube connected to the hydraulic means, an air control mechanism having an air jet and baffle controlled by said Bourdon tube, and means for adjusting the relation between said jet and baffle for establishing a predetermined pressure limit.

12. The combination set forth in claim 2 further characterized in that said pump for producing a constant fluid pressure is of the type having variable displacement from zero to maximum and said control means includes mechanism for reducing the displacement of said pump as one of said predetermined pressure limits is approached.

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