

[54] AUTOMATIC DEWATERING OF GAS WELLS

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[58] Field of Search: 166/53, 314

[56] References Cited

UNITED STATES PATENTS

1,754,946	4/1930	Haskell	166/53
2,296,833	9/1942	Boynton	166/53
3,266,574	8/1966	Gandy	166/53
3,396,793	8/1968	Piper et al.	166/53

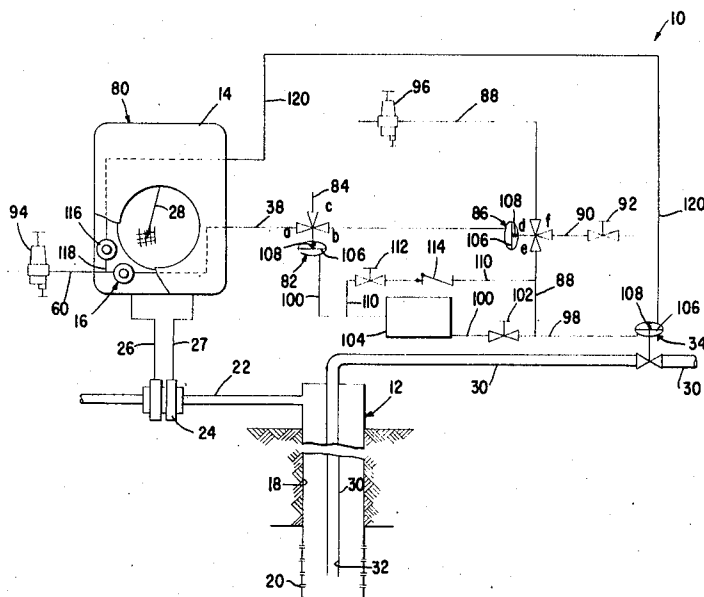
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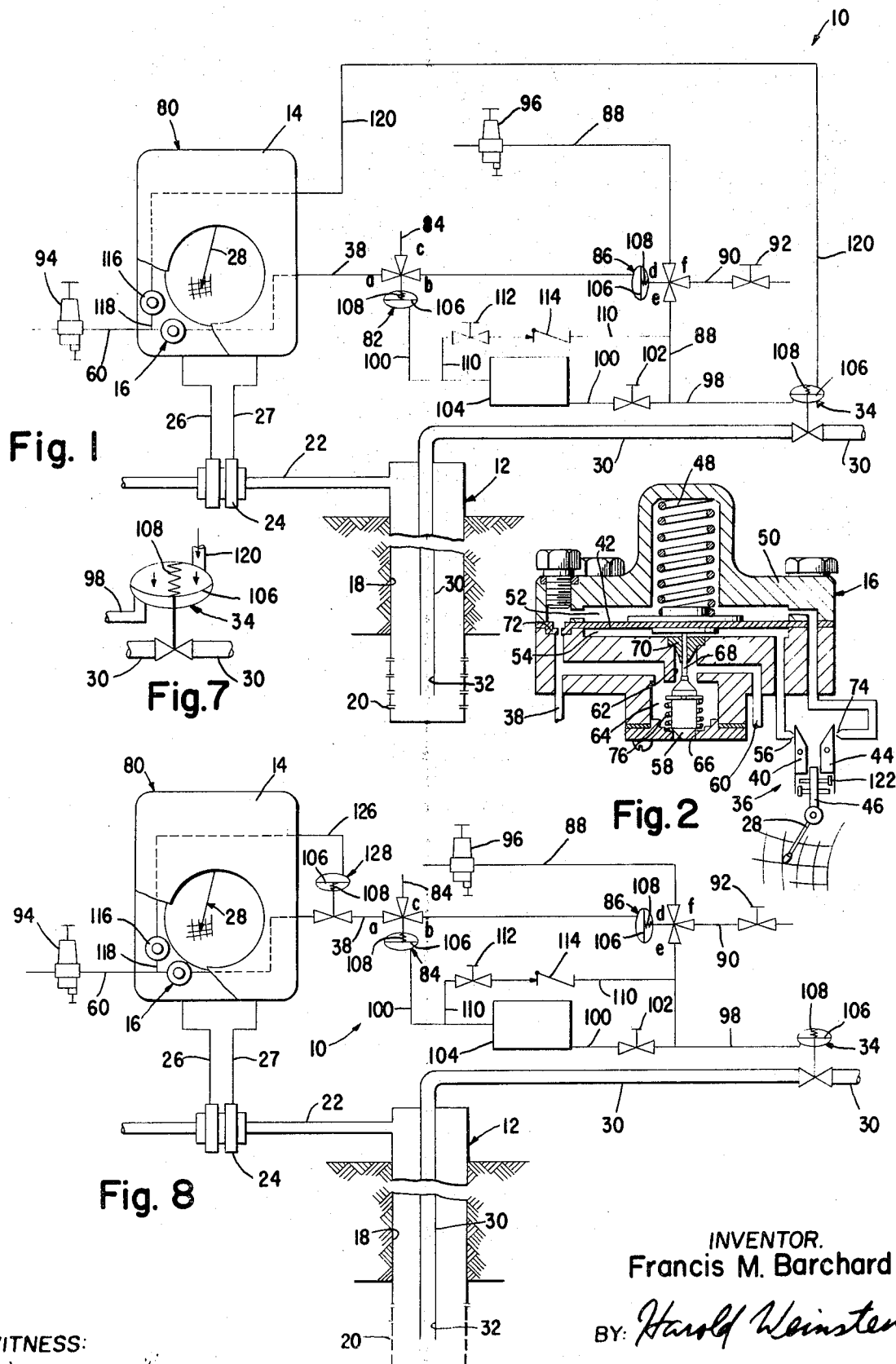
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[57] ABSTRACT

An automatic gas well dewatering system which operates to eject water from the well whenever the differential pressure across an orifice plate in the gas discharge line decreases below a predetermined low pressure value. The said dewatering system includes fluid activated control valves disposed in control loop lines to continuously cycle the control valves between open and closed positions. One of the control valves intermittently opens a liquid discharge line connected to a tubing carried in the well casing for discharging liquid from the well. The said dewatering system will continue to cycle and eject water from the well so long as the differential pressure across the orifice plate remains below a predetermined high pressure value.

16 Claims, 8 Drawing Figures





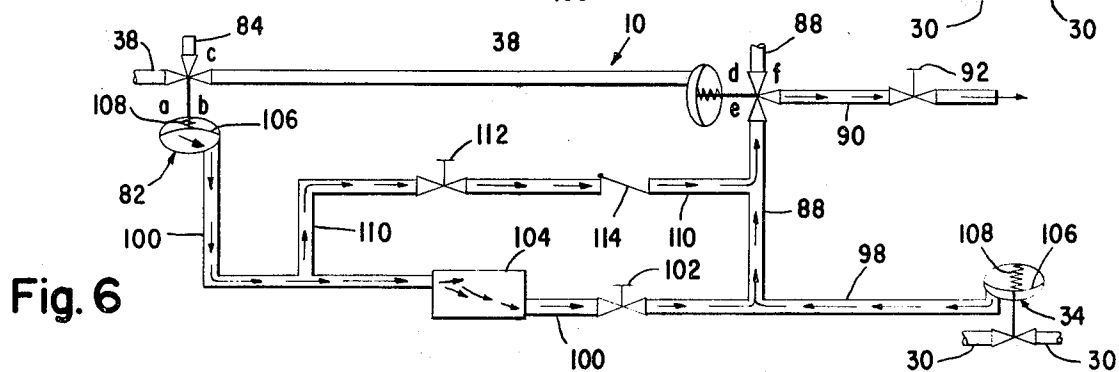
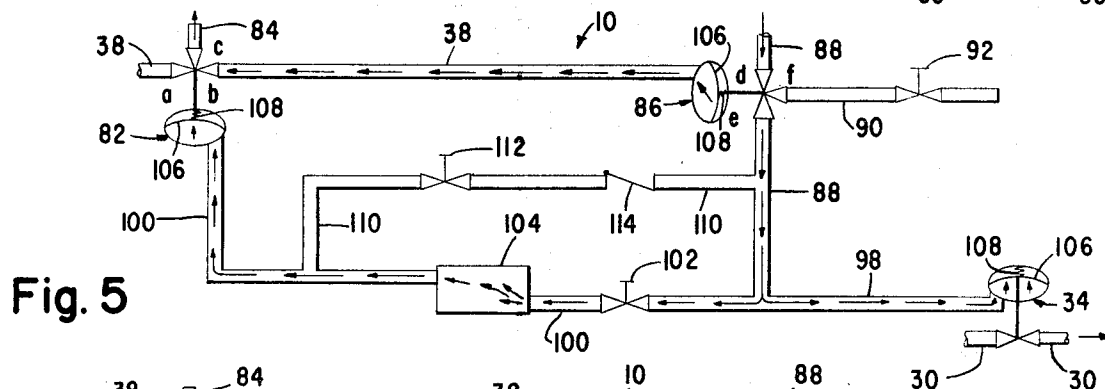
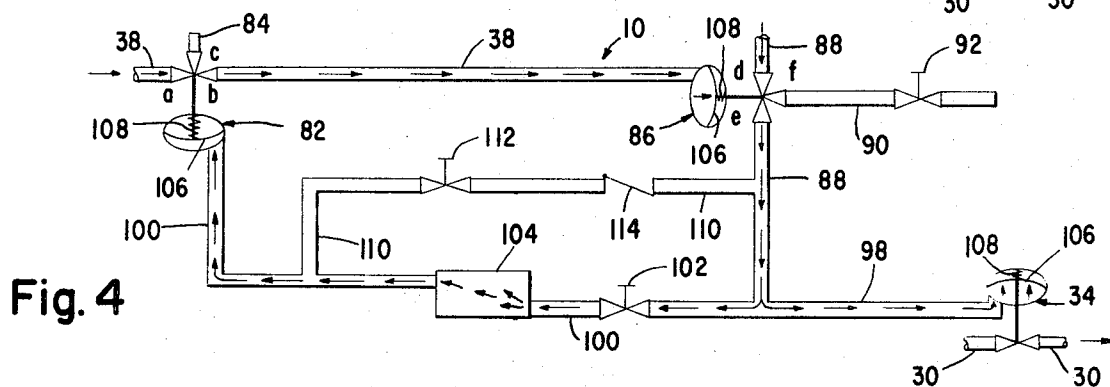
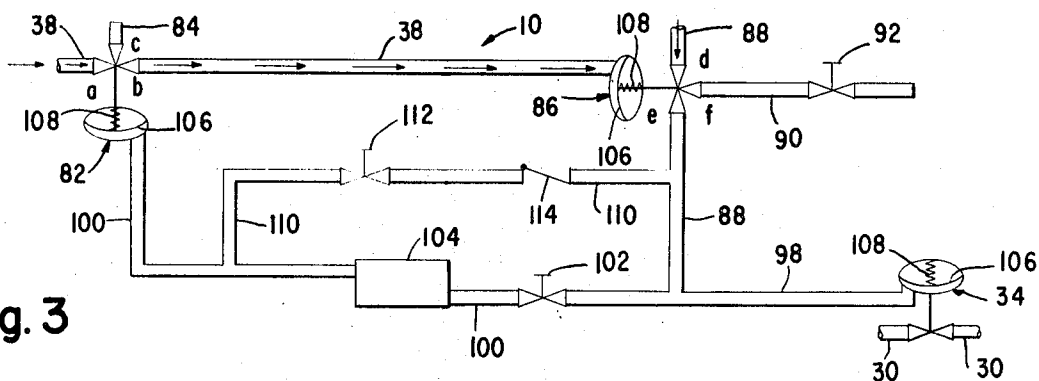
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AUTOMATIC DEWATERING OF GAS WELLS

BACKGROUND OF THE INVENTION

There are many gas wells that have been abandoned or are marginal producers due to the fact that problems are encountered with water entering the casing of the well and reducing or cutting off the gas production. The present methods of trying to produce gas in the presence of water have been based on some type of apparatus that operates on pressure difference between tubing and casing pressures, or some type of gas-lift apparatus usually inserted with, or in the tubing. Another approach is some type of time-intermitter that will allow the water to be ejected on a fixed or variable time basis. All of these methods have various disadvantages and have worked spasmodically and inefficiently at best.

SUMMARY OF THE INVENTION

One of the principal objects of the present invention is to allow the well to produce gas at its most efficient rate, and to eject the water from the well as soon as it interferes with or reduces the gas flow. In the present invention, the novel dewatering system will automatically eject the water when the differential pressure across an orifice plate decreases to a predetermined setting, indicating a lessening of gas flow and a watering-off of the well.

It is also an object of the present invention, to provide an improved automatic gas well dewatering system which overcomes the prior art deficiencies; which is simple, economical and reliable; which is activated responsive to a predetermined decrease in the differential pressure across the orifice plate and deactivated responsive to a predetermined increase in the gas flow differential; which operates intermittently to eject water from the well, which would otherwise interfere with the gas production thereof; and which uses a shut-off differential controller to shut down the dewatering system during periods of no gas flow or shut-in conditions.

It is a further object of the present invention to provide an improved automatic gas well dewatering system which has easy surface accessibility; which can complement present measuring equipment; which eliminates the need for any type of bottom hole equipment; and which is easy to install and adjust.

Other objects and advantages will be apparent from the following description of several embodiments of the invention and the novel features will be particularly pointed out hereinafter in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention is illustrated in the accompanying drawings in which:

FIG. 1 is a schematic illustration of an automatic gas well dewatering system embodying the present invention.

FIG. 2 is an elevational view, partly in section, of the differential controller used in the present dewatering system.

FIG. 3 is a diagrammatic view of the closed control loop of the present invention immediately after it has been activated.

FIG. 4 is a diagrammatic view of the closed control loop of the present invention in operation to eject water from the well.

FIG. 5 is a diagrammatic view of the closed control loop of the present invention during cycling of the control valves thereof, before shut-off of the water ejection.

FIG. 6 is a diagrammatic view of the closed control loop of the present invention during cycling of the control valves thereof, after shut-off of the water ejection, to initiate recycling of the system.

FIG. 7 is a diagrammatic view of the water dump valve in shut-off condition.

FIG. 8 is a modified schematic illustration of the automatic gas well dewatering system embodying the present invention.

DESCRIPTION OF THE INVENTION

In the illustrated embodiment of the invention shown in FIG. 1, the automatic gas well dewatering system 10 is used with a gas well 12 having a conventional recording orifice meter 14 of the type using a two-position controller or relay, designated generally as 16. The gas well 12 has a casing 18 with suitable perforations 20 for admitting gas and liquids from the surrounding formations. Any gas in the well will be withdrawn through gas flow line 22. An orifice plate 24 is connected in the gas flow line 22 to measure differential pressure across the orifice plate 24 which differential is transmitted through lines 26 and 27 to the orifice meter 14 to record the same through a manometer actuated pen arm 28. A tubing 30 is supported at the top of the casing 18 and extends downwardly therefrom to terminate in an inlet 32 near the bottom of the well at a point where the liquids will accumulate. To prevent indiscriminate discharge of liquid and gas through tubing 30, a normally closed pneumatically actuated valve 34 is connected into the tubing 30 at a location outside of the casing 18.

The two-position controller 16, depicted in FIG. 2, will be briefly described herein but a more complete explanation of this type of controller may be had by reference to U.S. Pat. No. 2,630,820. The two-position controller 16 is a pneumatic controller with a selected high-low pressure differential operational gap. It consists of a double flapper nozzle assembly 36 which controls the snap action of the controller 16 between the two stable operating conditions of (1) zero output of air pressure, and (2) full supply pressure through output line 38. Once the low limit flapper 40 is tripped, full output pressure remains on the diaphragm 42 until changing flow conditions in gas flow line 22 require the high limit flapper 44 to trip and shut down the flow in the output line 38. The flapper and nozzle assembly 36 impose no load on the orifice meter 14 and is actuated responsive to an actuator arm 46 fixedly connected to the pin arm 28 for movement therewith. The controller has a spring 48 biased against the diaphragm 42 mounted within the housing 50 to form an upper chamber 52 and a lower chamber 54. First, consider the conditions existing after tripping of the low limit flapper 40 when it is moved away from the nozzle 56 associated with the lower chamber 54, which occurs when the differential pressure across the orifice plate 24 drops below a predetermined low limit setting. The spring 48 biases the relay valve 58 to the open position shown in FIG. 2, so that supply pressure entering in line 60 will pass through aperture 62, valve chamber 64 to reach output line 38. The valve 58 is double acting, so that when it is in the position shown in FIG. 2, with the aperture 62 open, the lower end of the valve will close a vent aperture 66. The passage of pressure air through the output 38 will activate the automatic dewatering system, as explained more fully hereinafter, wherein water is dumped from the well 12 through tubing 30 to effect an increase in the gas discharge through gas flow line 22, resulting in an increase in the differential pressure across the orifice plate 24. As the differential increases it will allow the low limit nozzle 56 to re-close. However, the flow of pressure air from the supply line 60 to the output line 38, will continue after the low limit nozzle 56 is closed. The output pressure will drop to zero only after the high limit nozzle is opened when the flow through the gas flow line 22 exceeds the setting of the high limit flapper 44. Opening of the low limit nozzle 56 caused pressure in the lower chamber 54 to drop. The pressure in the lower chamber 54 is constantly fed from the supply through the restriction formed by the valve pin 68 and bushing 70. The dropping of the pressure in the lower chamber 54 allows the diaphragm spring 48 to force the diaphragm 42 down to seat the valve 58 against the bleed aperture 66 as shown in FIG. 2. This effects the opening of the supply aperture 62 to the valve chamber 64 and the output line 38. As the output pressure rises, the pressure in the upper chamber 52 rises through the secondary restriction 72. Now, if the low limit nozzle is re-closed, the pressure in the lower chamber 54 will

again rise to equal the pressure in the upper chamber 52, but will not force the diaphragm and the relay valve 58 because the diaphragm spring is sized to hold them down if the pressure in the lower chamber 54 is equal to or less than the pressure in the upper chamber 52. Upon the gas flow in the gas flow line 22 exceeding the setting of the high limit flapper 44, the actuator arm 46 will contact the same to open the high limit nozzle 74. This drops the pressure in the upper chamber 52 so that the pressure in the lower chamber 54 is now greater than the pressure in the upper chamber 52, and the diaphragm 42 is pushed up; the relay valve 58 follows, being pushed up by its spring 76. This closes the supply aperture 62 and opens the bleed aperture 66. The output pressure in output line 38 drops to zero, as does the pressure in the lower chamber 54, since the upper diaphragm chamber 52 communicates with the output pressure line 38 through the secondary restriction 72. Reclosing the high limit nozzle 74 will not cause the output pressure to rise again because the pressure in the upper chamber 52 is shut off from the supply line 60. The output pressure cannot rise until the low limit nozzle 56 is opened once again as described hereinbefore. The drop in the output pressure in line 38 will shut off the automatic dewatering system 10.

The term high-low differential controller designated generally 80, is used herein to mean the operative combination of the two position controller 16 and the recording orifice meter 14.

The automatic dewatering system 10 as shown in FIG. 1, includes a pneumatically actuated three-way valve 82 having legs *a* and *b* connected into output line 38 in a normally open position, and a third leg *c* connected to a vent line 84 which is normally closed. A second pneumatically actuated three-way valve 86 having legs *d* and *e* connected into a line 88 which delivers pressure air or gas from a suitable source with the leg *d* normally closed and the leg *e* normally open to the third leg *f*, which is connected to a vent line 90 having an adjustable throttle valve 92 therein. Each of the lines 60 and 88 have connected therein supply regulators 94 and 96 respectively, to set the pressure as desired which in the preferred embodiment shown in FIG. 1 for line 60 will be 20 psi and for line 88 will be between 30 to 40 psi. Downstream of the *e* leg of valve 86 the line 88 branches into line 98 and 100. The line 100 has an adjustable throttling valve 102 connected therein adjacent the line 88 and further downstream an accumulator 104 is also connected into the line 100. The line 100 terminates in the control dome of the valve 82 on the side thereof remote from the valve. The line 38 extends from the leg *b* of valve 82 to terminate in the control dome of the valve 86 on the side thereof remote from the valve. The line 98 extends from the line 88 to terminate in the control dome of the valve 34 on the side thereof adjacent the valve. Each of the valves 34, 82 and 86, have control domes with a diaphragm 106 and a spring 108 located therein as shown in FIG. 1. A bypass line 110 is connected between the line 100 and the line 88. The bypass line 110 has an adjustable throttling valve 112 and a check valve 114 which acts to direct the flow from line 100 through line 110 to line 88, and prevents flow in the opposite direction.

A second two-position controller 116, of the same general construction as controller 16, is connected to a supply line 118 which branches from the line 60 and has an output line 120 which terminates in the control dome of valve 34 on the spring side of the diaphragm.

The operation of the automatic dewatering system 10 is shown schematically in FIGS. 3-6 during which time the high-low differential controller remains in the "on" condition shown in FIG. 2 in which pressure air from supply lines 60 is delivered through output line 38. Pressure air or gas will be delivered through the output line 38 upon the gas pressure differential across the orifice plate 24 decreasing to a predetermined amount corresponding to the low limit setting of the controller.

The system 10 has built in adjustable delays as by means of adjustable valves 92, 102 and 112, which allow the dumped valve 34 to stay open a considerable length of time to permit

water to be ejected from the well 12 through tubing 30, to a suitable sump (not shown). The automatic dewatering system 10 will continue to open and close the dump valve 34 so long as the flow of gas in gas flow line 22 does not increase sufficiently to raise the gas pressure differential across the orifice plate 24 above the high limit setting of the controller 80. When sufficient water has been ejected from the well 12 to allow the gas to increase production, the gas pressure differential across the orifice plate 24 will increase, the differential controller 80 will cancel its output signal through output line 38 to effect shutdown of the automatic dewatering system 10, and the gas well 12 will be back on straight gas production until the gas pressure differential across the orifice plate 24 drops off again sufficient to result in reactivation of the automatic dewatering system 10 and a repeat of the water ejecting process.

As indicated by the oppositely extending screws 122 threadedly connected in actuating arm 46 as shown in FIG. 2, the gas pressure differential high and low set points are individually adjustably to permit setting thereof to meet the normal flowing conditions of any given well under production, and allow the well in question to stay on production at its best rate.

When the gas pressure differential across the orifice plate 24 starts to decrease, the differential controller 80 responsive to the gas differential reaching a predetermined low point, will give out a pneumatic signal of pressure air or gas through output line 38. The pressure air or gas is shown in output line 38 diagrammatically by the arrows in FIG. 3, and passes through normally open legs *a* and *b* of valve 82 to be introduced into the control dome of the valve 86 which is normally closed with respect to the pressure air in line 88 that reaches leg *d* of valve 86, but can go no further. The normally closed valve 34 prevents water from being ejected through tubing 30.

In the next step of the operation of the automatic dewatering system 10, as shown in FIG. 4, the diaphragm 106 of valve 86 is pressurized to trip the valve and open legs *d* and *e* of line 88 to the pressure therein, while closing leg *f*. Once open, pressure air in line 88 is transmitted as indicated by the arrows to line 98 to act on the diaphragm 106 of valve 34 to cause the same to open, thus permitting water to be ejected through tubing 30. Pressure air from line 88 is also delivered to line 100 as indicated by the arrows wherein it is fed into the accumulator 104 through the adjustable throttling valve or restriction 102 before reaching and acting on the diaphragm 106 of the valve 82. The result is that the valve 82 will trip more slowly than did valve 34 to permit the valve 34 to remain open a longer time. Another effect as is shown diagrammatically by the solid arrows in FIG. 4 is that pressure air remains in line 38 so as to continue to act on the diaphragm 106 of valve 86. At the instant of time depicted in FIG. 4, valves 34 and 86 have been tripped from the normally closed position to an opened position, while the valve 82 remains in its normally open position.

As the pressure continues to build in the control dome of valve 82 the pressure acting on diaphragm 106 thereof becomes sufficient to trip the valve 82, thus closing leg *a* from leg *b* and opening legs *b* and *c* thereof. FIG. 5 shows the automatic dewatering system 10 at the instant the valve 82 has tripped and prior to the valves 86 and 34 resuming their normal closed position. However, as is indicated by the direction of the solid arrows shown in line 38, the flow of the pressure air will be through legs *b* and *c* into vent line 84 to remove the pressure acting upon the diaphragm 106 of the valve 86 as is evidenced by the position illustrated in FIG. 6.

FIG. 6 shows the automatic dewatering system 10 the instant before the valve 82 returns to its normally open position (depicted in FIG. 3) but after valves 34 and 86 have been restored to their normally closed position. Once the valve 82 has been closed to block the flow of pressure air from leg *a* to leg *b* and to open the communication between legs *b* and *c*, the diaphragm 106 of valve 86 will lose its signal in that the pressure air will leave line 38 through vent line 84 causing the valve 86 to trip and assume the position shown in FIGS. 3 and

6, thus blocking the flow of pressure air in line 88 in that leg *d* is closed. Once valve 86 assumes its normal position, as shown in FIG. 6, legs *e* and *f* are connected so that pressure air will be discharged from line 88 via vent line 90. The pressure air discharged from line 88 is delivered thereto by line 98, and lines 100 and 110 respectively. The diaphragm 106 of the valve 34 loses its signal causing the valve 34 to trip in that the line 98 connects directly through line 88 to the vent line 90. In the case of the valve 82, the diaphragm will lose its signal as the pressure air passes out through adjustable throttling valves 102 and 112 of lines 100 and 110 respectively. The vent line 90 has an adjustable throttling valve 92 connected therein which may be set to adjust the unloading rate of each of the diaphragms 106 of the respective valves 34 and 82. In the case of the unloading of the diaphragm 106 of valve 82, adjustable valve 112 permits a variation between the loading and unloading time for valve 82 in that it can be set at a different rate of bleed then that of the loading valve 102, although some of the unloading is done through valve 102 at the same time. The check valve 114 insures that the loading of the diaphragm 106 of valve 82 is only accomplished through line 100. The adjustable throttling valves 102, 112 and 124, along with the size and location of the accumulator 104, determine how fast the water dump valve 34 opens and closes. When all of the pressure is bled from the accumulator 104, and therefore, also from the diaphragm 106 of the valve 82, the valve 82 trips to block off leg *c* and to once again connect legs *a* and *b*, thus allowing the pneumatic signal of pressure air in line 38 to reach and act on the diaphragm 106 of the valve 86. This starts a recycling of the process with the step shown in FIG. 3, and the whole process continues to repeat indefinitely, as long as the differential controller 80 continues to send an output signal through output line 38. The signal from the differential controller 80 can only be cancelled by an increase in the differential pressure across the orifice plate 24 of the orifice meter 14, responsive to an increase in the gas flow, and at such an increase in differential pressure the flow of pressure air in output line 38 will be cancelled to effect a closing of the dump valve 34.

The high set point of the differential controller 80, at which the pressure differential will act to cancel the output signal in output line 38 is infinitely adjustable, and can be determined for each gas well in question after a study of the respective gas well characteristics, as is the case with the initial differential low trip point which effects actuation of the automatic dewatering system 10. The three-way control valves 82 and 86 are operatively connected in lines 38 and 88 respectively to control the flow of pressure air in the line 38 and the respective lines 88, 98, 100 and 110, to form an interconnecting control loop to effect continuous cycling of the water dump valve 34 during operation of the automatic dewatering system 10.

It will be understood that the differential controller 80 operates such that the differential pressure across the orifice plate 24 can drop below the low trip point or increase to a value above the high trip point without interfering with the production of gas in the well 12, or the measurement of the gas flowing in gas flow line 22, as measured by the orifice meter 14.

Once the differential controller 80 actuates the automatic dewatering system 10 responsive to a decrease in the pressure differential across the orifice plate 24, as long as the differential pressure across the orifice plate 24 remains below the high trip point the dumping procedure will continue to open and close the dump valve 34 indefinitely, which could create a problem if the gas flow line were shut-in, in which case there is no gas flowing. In such a case, the water dump valve 34 would begin to dump gas after all the water in the well 12 had been dumped. To avoid this, the differential controller 80 can be fitted with the second two-position controller 116 which sends out a pneumatic signal in line 120 responsive to the shut-in condition. In other words, the relay or controller 116 would be actuated to send pressure air in the output line 120 when the pressure differential across the orifice plate 24 reached zero

corresponding to the occurrence of the shut-in condition. The pressure air in line 120, as shown in FIG. 7 is delivered to the spring side of the diaphragm 106 of valve 34 to close it against the pneumatic signal which would be sent to the opposite side of the diaphragm 106 through line 98. Thus, upon actuation of the controller 116, the valve 34 would be locked in the closed position.

A second embodiment of the invention is shown in FIG. 8 in which the differential controller 80 and the automatic dewatering system 10 is the same as that shown in FIG. 1 with the exception of the output line 126 from controller 116 is directed to a pneumatically actuated normally open valve 128 connected into the output line 38. It is understood that the valve 128 and the connecting line 126 of FIG. 8 replaces the line 120 used in the embodiment of FIG. 1, but in all other respects the differential controller 80 and the automatic dewatering system 10 will function in the same manner and with the same components as was shown and described herein with respect to the FIG. 1 embodiment. Therefore, except as has already been noted the reference characters will be the same as that used hereinbefore.

Accordingly, the controller 116 has a low limit setting which will be actuated to send a signal through output line 126 when the differential across the orifice plate 24 reaches zero to indicate the shut-in condition. The signal in line 126 will act upon the diaphragm 106 mounted in the control dome of the valve 128 to close the valve and shut off the output line 38. Thus, actuation of the controller 116 depicted in either embodiment of the invention shown in FIGS. 1 and 8, responsive to the differential across the orifice plate 24 reaching zero, the automatic dewatering system 10 will be shut down in each instance.

The controller 116 has a high trip setting point which is actuated when the differential across the orifice plate 24 increases with the opening of the gas flow line 22. When this occurs the output signal whether it be in output line 120 or output line 126, will be cancelled to restore the automatic dewatering system 10 to its operative condition during normal flow of gas from the well 12.

Each gas well has different operating characteristics, so that it may be necessary to have an initial testing period to determine the most desirable high and low trip points for setting of the two-position controller 16.

If gas production in any well increases to such an extent that a larger orifice plate is required, then new high and low trip points for the controller 16 would have to be established to satisfy the new operating differentials of the orifice meter 14.

It will be understood that various changes in the details, materials, arrangements of parts and operating conditions which have been herein described and illustrated in order to explain the nature of the invention may be made by those skilled in the art within the principles and scope of the invention.

Having thus set forth the nature of the invention what I claim herein is:

1. In a gas well having a casing in which liquid collection would interfere with the gas production, the combination of:

- a. a gas flow line connected to the casing of the well to discharge the gas therefrom,
- b. an orifice plate in the gas flow line,
- c. a differential controller operatively connected to the gas line to measure the differential pressure across the orifice plate,
- d. a tubing supported in the casing and having its lower end open adjacent the bottom of the casing,
- e. a liquid discharge line connected to the tubing,
- f. a normally closed dump valve means connected in the liquid discharge line,
- g. a first control line for pressure fluid,
- h. a second control line for pressure fluid,
- i. control means operatively interconnecting the first control line and the second control line to form an operative loop having a predetermined cycling period in which

- pressure fluid is transmitted alternately in said first control line and said second control line,
- j. the control means operative responsive the differential controller and being initiated by a first predetermined pressure differential in the gas flow line and terminated by a second predetermined pressure differential in the gas flow line, and
 - k. the dump valve means is connected to one of the control lines to be opened upon pressure fluid being transmitted therein to discharge the liquid in the casing out of the tubing during the cycling period of the said one of the control lines.
2. The combination claimed in claim 1 wherein:
- a. the first control line is connected to operate the dump valve means,
 - b. the second control line is connected to the differential controller, and
 - c. the control means including a first control valve means connected in the first control line and operative responsive pressure fluid in the second control line, and a second control valve means connected in the second control line and operative responsive pressure fluid in the first control line.
3. The combination claimed in claim 2 wherein:
- a. the first control valve means includes a three-way valve normally closing the first control line and biased open by pressure fluid flowing in the second control line,
 - b. the second control valve means including a three-way valve normally opening the second control line and biased close by pressure fluid flowing in the first control line, and
 - c. the first control line and the second control line successively alternately operative to continuously cycle the dump valve means open and closed during operation of the control means.
4. The combination claimed in claim 3 wherein:
- a. the first control line includes a loading means downstream of both the first three-way control valve and dump valve means to delay the operation of the second three-way control valve in the second control line, and
 - b. the first control line includes an unloading means downstream of the loading means to coact with the loading means in removing pressure fluid from the second three-way control valve.
5. The combination claimed in claim 4 wherein:
- a. the loading means includes an accumulator and adjustable restriction connected upstream of the accumulator to set the operative rate of the second three-way control valve, and
 - b. the unloading means includes an adjustable restriction and check valve connected in a bleed loop line downstream of the accumulator to circulate back into the first control line intermediate the first three-way control valve and the adjustable restriction of the loading means.
6. The combination claimed in claim 5 wherein:
- a. each of the three-way control valves includes a bleed line connected to the third leg thereof with the first and second legs thereof connected across the respective first control line and the second control line.
7. The combination claimed in claim 1 wherein:
- a. a shut-off differential controller operatively connected to the gas line to measure a substantial zero differential pressure across the orifice plate, and
 - b. the shut-off differential controller operatively connected to the control means to effect closing of the dump valve means whereby gas flow will not be discharged from the dump valve means during shut-in conditions of the gas well.
8. The combination claimed in claim 7 wherein:
- a. a shut-off valve means is connected in one of the control lines in a normally open position and connected to be closed by operation of the shut-off differential controller upon the differential pressure across said orifice plate reaching substantially zero.

9. The combination claimed in claim 7 wherein:

- a. a third control line connected between the shut-off differential controller and the dump valve means, whereby on operation of the shut-off differential controller, the dump valve means is locked in the closed position.

10. In a gas flowing well having a casing in which liquid collection therein interferes with the gas production of the well, the combination of:

- a. a gas discharge line connected to the casing,
- b. a differential controller including an orifice plate connected into the gas discharge line to measure the differential pressure across the orifice plate,
- c. a control device operative responsive the differential controller sensing a differential pressure within a predetermined range of gas flow pressure in the gas discharge line,
- d. the control device including control loop lines having fluid actuated control means therein to continuously cycle said control loop lines open and close for predetermined cycle periods during operation of the control device,
- e. a tubing connected into the casing with an open lower end positioned adjacent the bottom of the casing, and a normally closed outer end, and
- f. one of the fluid actuated control means connected into the tubing intermittently to open said outer end thereof for discharging liquid for predetermined cycle periods during operation of the control device.

11. The combination claimed in claim 10 wherein:

- a. a second differential controller means to sense the differential pressure across the orifice plate, and
- b. the second differential controller means is connected in the control device to become operative upon the said differential pressure reaching substantially zero to operate the control device to prevent the said outer end of the tubing from opening.

12. The combination claimed in claim 10 wherein:

- a. the control loop lines includes a control line connected to the differential controller, and a recycle line connected to a source of pressure fluid and having two branches,
- b. the control means includes a plurality of valve means, having fluid actuations; one connected in the control line normally in open position, one connected in the recycle line normally in closed position, and one connected in the tubing normally in closed position, and
- c. the control line is connected to the actuator of the recycle line valve to open said valve upon being actuated responsive the differential controller, whereby pressure fluid is transmitted in the recycle line to the actuators of the control line valve to close the same, and the tubing to open the same, thus causing a shut down of the recycle line valve and a continuous cycling of the liquid discharge so long as the differential controller is operative.

13. The combination claimed in claim 12 wherein:

- a. loading means is connected in the recycle line to extend the transmission period of the pressure fluid to the actuator of the control line valve to delay the closing thereof.

14. The combination claimed in claim 13 wherein:

- a. the last mentioned means including an accumulator and an adjustable restriction delivery pressure fluid thereto, and
- b. unloading means is connected in the recycle line including an adjustable restriction and a check valve to direct flow of pressure fluid out from the actuator of the control line valve to speed-up the unloading thereof.

15. The combination claimed in claim 14 wherein:

- a. the control line valve is a three-way valve with two legs connecting the control line normally open and the third leg defining a bleed line, and
- b. the recycle line valve is a three-way valve with two legs connecting the recycle line normally closed and the third leg defining a bleed line.

16. The combination claimed in claim 15 wherein:

- a. each of the three-way valves in the respective control line and the recycle line having an open position which con-

nects the opposite loop of said lines and closes the bleed line, and a closed position which shuts off the leg on the side of said lines, transmitting the pressure fluid and connects the leg on the side of line communicating with the actuator of the respective valves to the bleed line.

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