Jan. 16, 1940. R. J. S. PIGOTT 2,187,662

CONTROLLER FOR GAS FLOW

Filed Aug. 17, 1938 2 Sheets-Sheet 1

FIG. 1.

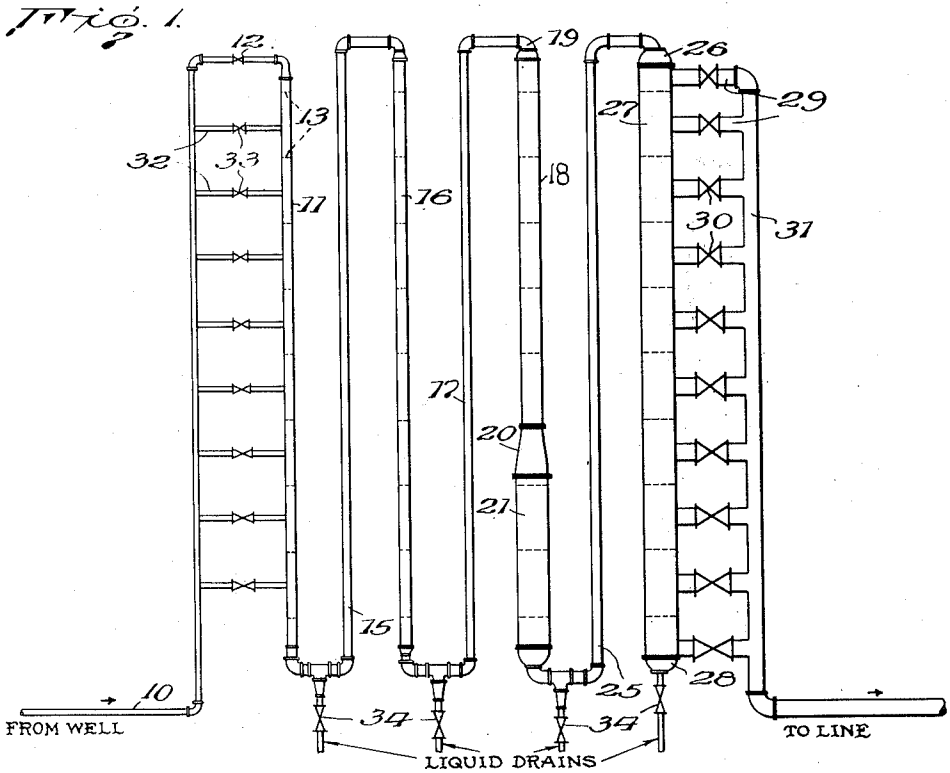



FIG. 2.

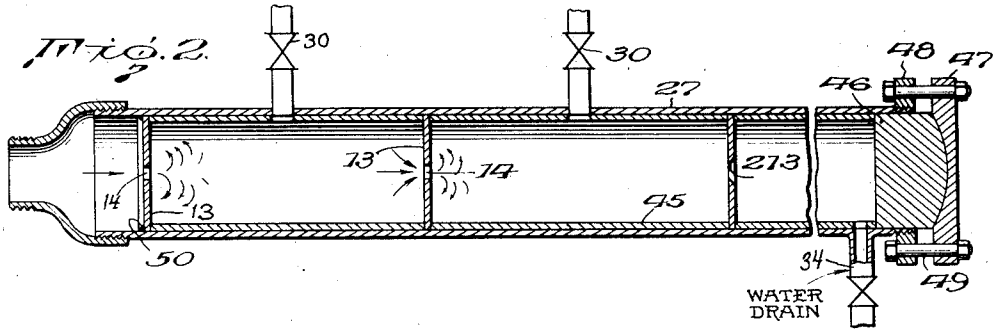



FIG. 3.

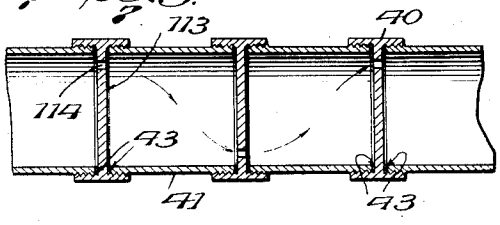
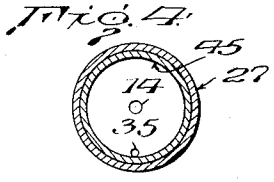



FIG. 4.




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Jan. 16, 1940. R. J. S. PIGOTT 2,187,662

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Filed Aug. 17, 1938 2 Sheets-Sheet 2

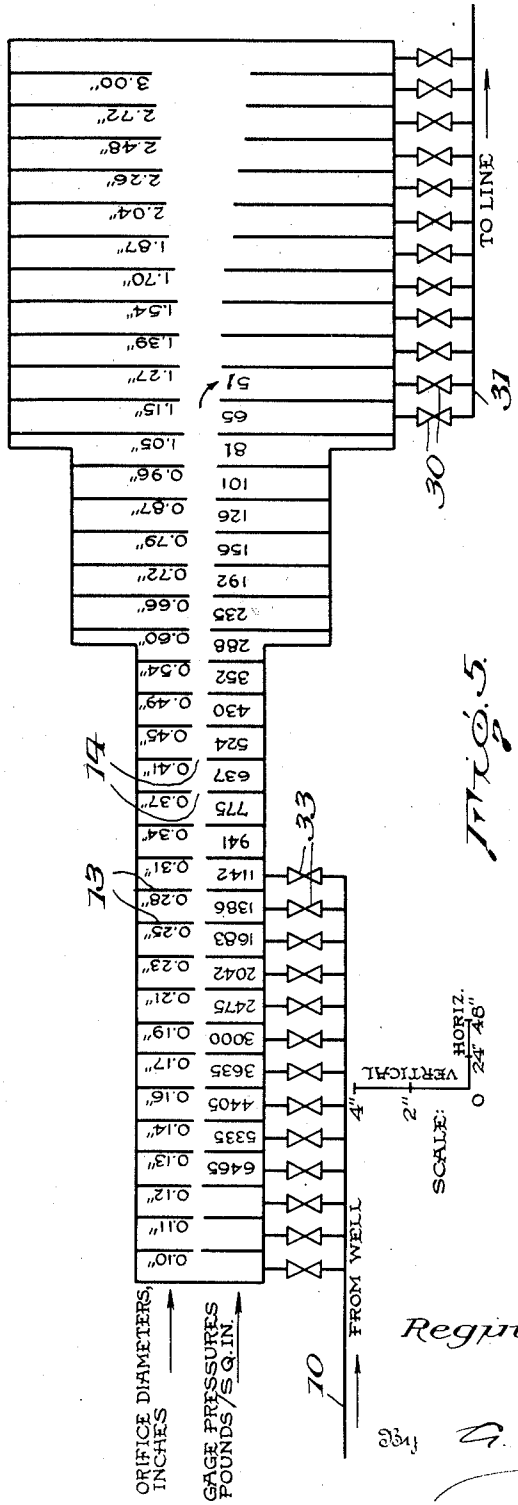



FIG. 5.

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# UNITED STATES PATENT OFFICE

2,187,662

## CONTROLLER FOR GAS FLOW

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Application August 17, 1938, Serial No. 225,454

5 Claims. (Cl. 138—44)

This invention or discovery relates to controllers for gas flow; and it comprises apparatus for methodically reducing the pressure of flowing gases from gas wells and the like, including conduit means adapted to be connected to a source of gas under high pressure, and means providing a plurality of orifices spaced along the length of the conduit at intervals, the diameters and spacings of the orifices being so correlated as to cause at each orifice a velocity increase and corresponding temperature drop less than that which would result in freezing of moisture in the gas; all as more fully hereinafter set forth and as claimed.

In natural gas wells, gas is often produced in large volumes and at very high pressures. Its pressure must be reduced to a moderate value for transmission to pipe lines or other point of use. In the early stages of development of gas fields, a single well may produce a million or more cubic feet of gas (measured at atmospheric pressure and room temperature) per day, at pressures of the order of 3000 pounds per square inch or more, in typical cases. The conventional way of handling the gas flow is to pass it through a reducing or throttling valve. This expedient is only satisfactory when gas pressures are very low, e. g. in the late stages of development of a field. It is not satisfactory in dealing with the high pressures described. This is partly due to the severe wear on the mechanical parts caused by the rushing gas stream (which may contain corrosive gases) and partly because of the tendency for water vapor in the gas stream to condense as snow or frost in the outlet side of the valve. Gas flows experience a temperature drop on throttling, i. e. on passage through an orifice or the equivalent. This is because of transformation of thermal energy into kinetic energy with resultant drop in temperature. The temperature drop is substantial when a high pressure stream is throttled by an orifice, and under gas field conditions, the drop across the reducing valve is usually enough to bring the gas temperature well below the freezing point of water (32° F.) with the result that ice and snow collect in the valve. This causes erratic regulation, and, when the ice deposit builds up unduly, necessitates a complete shutdown, which is often highly inconvenient. It has been proposed to employ heating jackets, etc., for the reducing valve, but such devices give trouble and are wasteful. Pressure reduction by frictional resistance on passing gas through long coils of pipe has disadvantages, including the necessity of providing great lengths of piping.

According to the present invention there is provided an improved system for dealing with high pressure flows from gas wells, which is based on the discovery that by methodically reducing the pressure of the flowing gas, in a large number of decrements, by orifice throttling, the temperature drop at any point in the system can be made less than that which would result in freezing of moisture, and trouble from this source is thereby obviated. With high pressure gas flows the drop must be divided into a rather large number of decrements, to achieve this end. The most efficient pressure-reducing instrumentality known is a thin sheet provided with a sharp-edged hole, and in the best embodiments of the invention I approximate such an arrangement by employing a series of thin orificed plates, spaced from each other by distances great with respect to the orifice diameters, and large enough so that the velocity imparted to the steam due to passage through any one orifice, is reduced practically to zero by turbulence before the stream enters the next orifice. Enough of the orifices are provided to reduce the high pressure gas flow to the desired low pressure. To keep a constant temperature drop at each orifice, the diameters of the orifices are made progressively larger toward the outlet end, and the diameters are so proportioned that the temperature and pressure drop across each one is less than would cause freezing of moisture. To have the temperature drop constant at each orifice the area of any given orifice is made to have a substantially constant ratio to the area of the preceding orifice in series. With a perfect gas, this orifice area ratio would be exactly constant. Natural gas departs somewhat from the perfect gas laws, but in manufacturing it is convenient, and quite satisfactory, to employ an exactly constant ratio between orifice areas, as described in detail below.

In the accompanying drawings there are shown, more or less diagrammatically, two examples of specific embodiments of apparatus within the purview of the invention and capable of carrying out the method. In the showings,

Fig. 1 is a view in elevation, more or less diagrammatic, of a complete pressure reducing apparatus,

Figs. 2 and 3 are sectional views of two convenient orifice arrangements,

Fig. 4 is an elevation view of a modified form of orifice disk, and

Fig. 5 is a diagrammatic view to illustrate the proportioning of the orifice series.

Referring to the drawings, Fig. 1 shows the apparatus or flow bean applied to a gas line 10 running from a gas well (not shown) and carrying a high pressure flow of gas. The gas produced at most gas wells has a temperature around 80° F. A vertical conduit 11 receives the gas, through a valve 12. Within the conduit are a plurality of orificed disks designated collectively by 13 and orificed at 14, spaced at equal intervals, and of orifice diameter progressively increasing, according to the principles described below. The flow of gas on passing through the first orifice in its path is reduced in pressure and temperature; the orifice diameter being so selected that the temperature drops to a point above freezing (32° F. or 0° C.). The spacing from the first orifice to the second is made great enough (usually at least 2 pipe diameters) so that the temperature of the gas rises substantially to its original value due to internal friction, before the gas flow reaches the second orifice. The same conditions hold throughout the system. Thus, at a point in the conduit just ahead of any orifice, the temperature is substantially the same as the temperature of the gas coming from the well, and at a point just behind (downstream) any orifice, the temperature is low, but is above 32° F. The pressure in each inter-orifice space is progressively lower away from the inlet end of the apparatus.

Referring to Fig. 2, the gas approaches each orifice at very low velocity, and flows through it as a high speed jet. The jet breaks up into eddy currents and the original temperature is substantially restored, by conversion of the kinetic energy of the jet into heat due to internal friction, before the gas reaches the next jet.

Pipe 11 and the orifices therein are conveniently of relatively small diameter; e. g., assuming the well gas line 10 to be 2-inch pipe, pipe 11 may be 4-inch pipe, and the orifice diameters may increase from say 0.1 inch at the inlet end, to 0.5 inch at the outlet end. The considerations governing the selection of the dimensions of the several apparatus parts are set forth in detail below.

The gas, after leaving the lowermost orifice in pipe 11, passes upward through an uptake 15 and thence into a second pipe 16 quite similar to pipe 11 except that the set of orifices therein are larger than in pipe 11. The gas leaving the lowermost orifice flows up through an uptake 17 to a third orifice-pipe 18, connections being made through a reducer 19. Pipe 18 is joined through a conical fitting 20 with a larger orifice pipe 21. Gas leaving the lowermost orifice in pipe 21 flows through an uptake 25 and a reducer 26, to a fourth orifice-pipe 27. The gas, by the time it reaches the orifice system of pipe 27, is reduced to a quite moderate pressure. The lower end of pipe 27 is blocked off at 28, and gas is taken off at any desired point along the pipe depending on the effluent pressure wanted. For this purpose a manifold arrangement is provided as shown, consisting of a plurality of bypasses 29, each valved at 30 as shown, tapping the several inter-orifice regions, and delivering to a common outlet pipe 31 running to the pipe-line pumps or other point of use, not shown. In operation, some one of the bypass valves is opened and the rest are closed. A corresponding manifold system is provided for the inlet end of the orifice series, so as to enable adjustment for different inlet pressures (well pressures). Thus a set of bypasses 32, valved at 33, is arranged as shown, connecting pipe 10 with the several inter-orifice spaces in pipe 11. If the well pressure is extremely high, valve 12 is opened and all valves 33 are closed, so that the gas flows through the entire orifice system in pipe 11, while if the well pressure is low, one of the lower bypasses is used, the remaining valves being closed.

The piping assembly is advantageously arranged vertically, as shown, so that moisture or natural gasoline condensing therein drains out by gravity. Drain valves 34 are provided for the outlet ends of the orifice-pipes, as shown. Should it be desired to mount the piping horizontally, the orifice disks may be provided with a second orifice 35, at the bottom of the rim thereof (Fig. 4), so that condensed moisture drains out horizontally, from the high pressure end to the low pressure end, under the influence of the gas pressure. In such arrangement the main orifice 14 is made somewhat smaller than when the bottom perforations are not used, the effective orifice area being the sum of the areas of the two orifices.

The absolute dimensions of the apparatus are important. In the apparatus of Fig. 1, the diameter of pipes 10, 11, 15, 16, 17, 18, 21, 25, 27 and 31, may conveniently be 2, 4, 3, 4, 3, 8, 12, 4, 12 and 6 inches respectively, and the apparatus may be 18 feet high.

Following are the considerations governing the selection of the various orifice spacings and diameters.

(a) The diameter of the pipe is advantageously at least 3 or 4 times the diameter of the orifices therein. This is so that the velocity of approach of the gas to each succeeding orifice will be reduced to a negligible amount. With a much lower ratio of pipe diameter to orifice diameter, the gas arriving at the next orifice will have substantial residual velocity and the next orifice will flow more gas than if the approach velocity were negligible. On the other hand, using a larger ratio than that indicated does not result in an improvement commensurate with the extra cost and weight.

(b) The spacing between the orifice disks is at least equal to the pipe diameter, and, better, twice the pipe diameter, so as to permit diffusion of the high speed stream issuing from any one orifice before it reaches the next orifice. Here again, a much closer spacing detracts from the effciency of the system while a greater spacing is unnecessary.

The inter-orifice spacing can be made closer, if desired, while preserving the same degree of restrictive effect, by locating the orifices not at the center but near the rim of the disks, and staggering the orifices as shown in Fig. 3. In Fig. 3, the orifice disks 113 with eccentric orifices 114 are provided with integral couplings 40 and are spaced by short pipe sections 41; the couplings and pipe sections being provided with straight (not tapered) threads 42 and gaskets 43 of lead or other suitable material being arranged as shown to provide a tight seal.

(c) Each orifice is made of such diameter that speed of gas flowing through it (taking into account the pressures on the upstream and downstream sides of the orifice) will not exceed a value such as would correspond to a temperature drop sufficient to bring the temperature down to 32° F., or some other higher temperature selected. For example, with natural gas, a velocity of approximately 700 feet per second occasions a drop

of 25° F. If the temperature of the influent gas is 80° F., and each orifice is proportioned to cause a velocity of 700 feet per second, the temperature of the gas leaving the first jet will be about 55° F. By the time the gas reaches the second jet the original temperature will be almost restored, due to eddy currents, and the temperature at the outlet of the second jet will be practically 55°. The local depression in temperature of the gas is approximately proportional to the square of the jet speed at any orifice. Thus in this example the orifice should not be so small as to cause a velocity of 900 feet per second, lest the temperature in the jet drop below freezing.

(*d*) The orifices are sharp-edged on the upstream side, and are advantageously formed in disks as thin as in conveniently practicable. Convenient proportions of orifice and disk are shown in Fig. 2. If desired, the orifice can be tapered in the form of a shallow cone, as indicated at **213** in Fig. 2, if the pressure difference across the disk is sufficient to require a heavier plate to avoid dishing.

Thicker plates, with consequently longer fluid passages, can be used while retaining many of the advantages of the invention; short nozzles can be used.

Fig. 5 shows the system in schematic form, to bring out the relation of the various orifices. In Fig. 5, the vertical scale is about 24 times the horizontal scale; so that the figure is longitudinally compressed and does not show the actual spacings. Referring to Fig. 5, some 37 orifices are shown in series, ranging in diameters from 0.1 inch at the inlet to 3 inches at the outlet. The actual diameters for a typical installation are marked on the figure. The diameter of each succeeding orifice is about 10 per cent greater than that of its preceding orifice, as shown.

Assuming a gas inlet pressure of 3000 pounds per square inch and a quantity of 1,350,000 cubic feet per day, the flow is admitted ahead of the orifice having a diameter of 0.19 inch as shown in Fig. 5, and pressure drop occurs at each orifice as marked on the figure. The pressure drop across the orifices decreases toward the outlet end, but the ratio of pressures in the conduit on the two sides of any given orifice is substantially constant; all as is apparent from Fig. 5. Assuming it is desired to take off gas at a pressure around 50 pounds per square inch, the valve is opened, corresponding to the 51 pound interorifice space. Should it be desired to take off gas at a lower pressure, one of the valves to the right of the figure is used. In case the quantity of gas to be handled is the same, i. e., 1,350,000 cubic feet per day, and the pressure is higher than 3000 pounds, for example 4,405 pounds per square inch, the valve in the line entering the interorifice space, labeled 4,405 pounds, would be opened and the other valves in the inlet manifold leads closed. The discharge pressure desired would be obtained in a similar manner. In case the quantity is different, for example 2,000,000 cubic feet per day instead of 1,350,000 cubic feet per day, and the pressure is 3000 pounds per square inch, the procedure to follow in selecting the right series of orifices is somewhat different from that for a pressure change only, as explained below. The orifice size corresponding to the pressure available, or 3000 pounds in this example, is taken as a basis for determining the proper size of initial orifice to take care of the increase in quantity. The diameter of the orifice for 3000 pounds is given as 0.19 inch in Fig. 5. Since 2,000,000 cubic feet are approximately 50 per cent greater than 1,350,000 cubic feet, an orifice must be chosen that has an area 50 per cent greater than the orifice having 0.19 inch diameter, which in this case is the orifice having a diameter of 0.23 inch. The pressure drops given in Fig. 5 will still obtain except that they will be moved two places to the right, i. e. 3000 pounds will take the position of 2,0[illegible] pounds and 2475 pounds will take the position of 1683 pounds etc.

The same procedure would be followed for a smaller quantity, i. e., the orifice chosen is of area having the same ratio to the orifice in Fig. 5 corresponding to the pressure available, that the quantity per day to be handled has to 1,350,000 cubic feet.

The above procedure is given only for the purpose of fully explaining the basis of selecting the proper group of orifices to handle a given quantity of gas at a given pressure and would be followed by the designer only in determining the pressure and capacity rating of the various designs decided upon to meet the demand. Each unit or group of units is given a name plate rating which would serve as a basis for properly applying the correct number and size of orifices required for any given well.

Fig. 2 serves to show one convenient way of mounting the orifices. The orifice disks **13** are spaced inside the pipe by sleeves **45** of smaller diameter pipe as shown. A header is arranged to close one end of the pipe as shown. It comprises a cylindrical block **46** fitting the pipe, a cap **47** and a flange **48** held together by bolts and nuts **49**. The disk at the other end of the pipe is welded in place as indicated at **50**. In this arrangement, to secure perfect seals at the disk, gaskets of lead or other suitable material are advantageously provided as in the arrangement of Fig. 3.

The apparatus is embodied in steel of the type ordinarily employed for gas piping, etc. for gas wells, and can be lagged if desired when used in regions of low weather temperatures.

While the apparatus has been described in connection with gas wells, it is also useful to control the gas flow from oil wells. In the early stages of development of oil fields, gas is sometimes produced along with the oil under high pressures, and the present invention provides a convenient way of handling the gas.

To avoid excessive valving in the two manifold systems, it is sometimes convenient to make up stacks of orifices in pipes as in Fig. 2 or coupled together as in Fig. 3, and bolt the stacks in or remove them as required.

Fig. 1 shows a complete system adapted for handling gas flows of the highest pressures which are ever encountered, and reducing the pressure to very low figures. In case such extremes are not encountered, the apparatus can be simplified in obvious ways. Sometimes the whole set of orifices can be embodied in a single 20 foot pipe.

What I claim is:

1. An apparatus for reducing the pressure of high-pressure moist gas, comprising an elongated conduit arranged for introduction of gas adjacent one end thereof and withdrawal of gas adjacent the other end, and a plurality of orificed obstructing means in spaced series in the conduit, spaced apart sufficiently so that the gas temperature reduction at each orifice is substantially restored by turbulence in the conduit before the gas reaches the next orifice in series, the orifices of the obstructing means being of geometrically in-

creasing orifice area toward the outlet end of the conduit so that the ratio of pressures across any two orifices in series is substantially the same and the maximum velocity and minimum temperature at each orifice are substantially constants, the number of orificed obstructing means being large enough and said orifice area ratio being small enough to maintain the gas temperature at any point above the freezing point of the moisture present in the gas.

2. The apparatus of claim 1 wherein the orificed obstructing means are disks in the conduit, provided with sharp-edged orifices therethrough.

3. The apparatus of claim 1 wherein the ratio of the orifice diameter of each of the orificed obstructing means, to that of the preceding orificed obstructing means in series, is about 11:10.

4. The apparatus of claim 1 wherein the conduit diameter is at least approximately seven times the orifice diameter of the obstructing means.

5. The apparatus of claim 1 wherein the orificed obstructing means are spaced apart by at least the diameter of the conduit.

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