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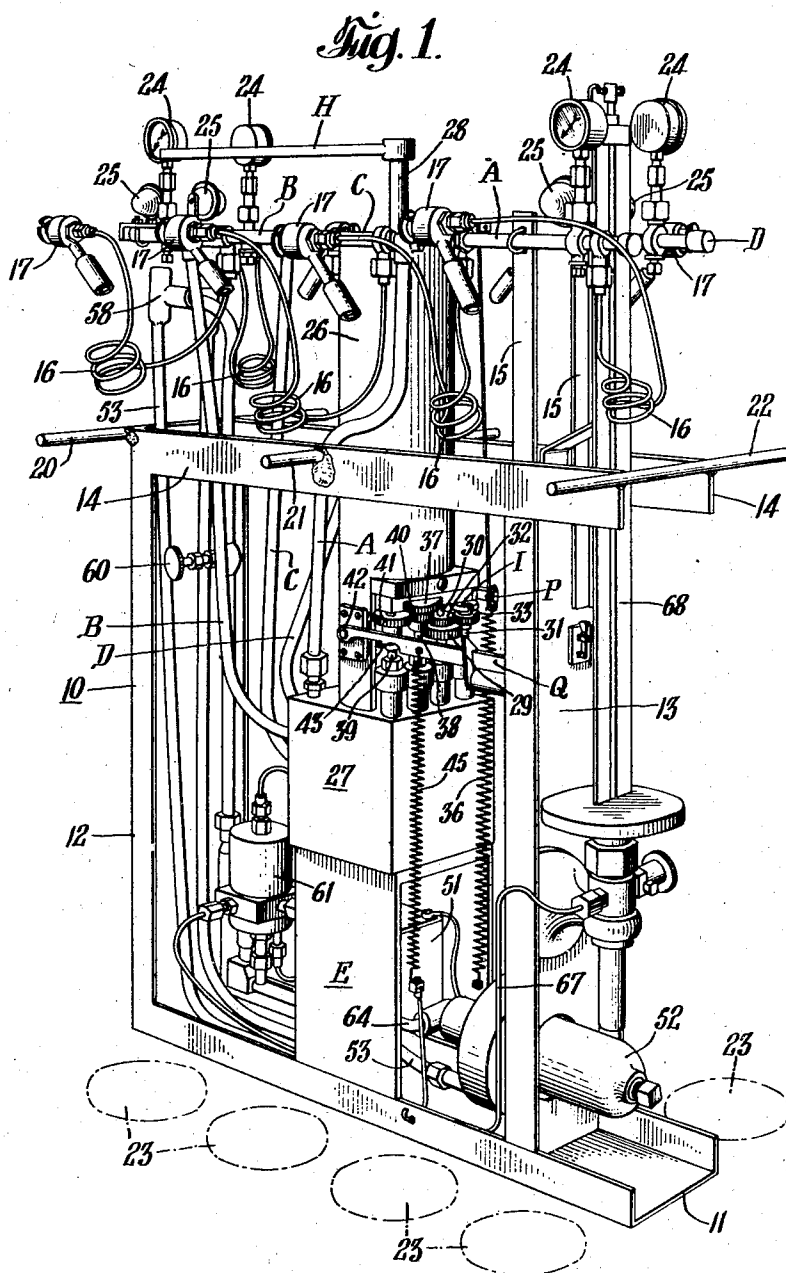
G. H. SMITH

2,411,235

APPARATUS AND METHOD FOR FILLING GAS STORAGE CYLINDERS

Filed Feb. 11, 1943

5 Sheets-Sheet 1



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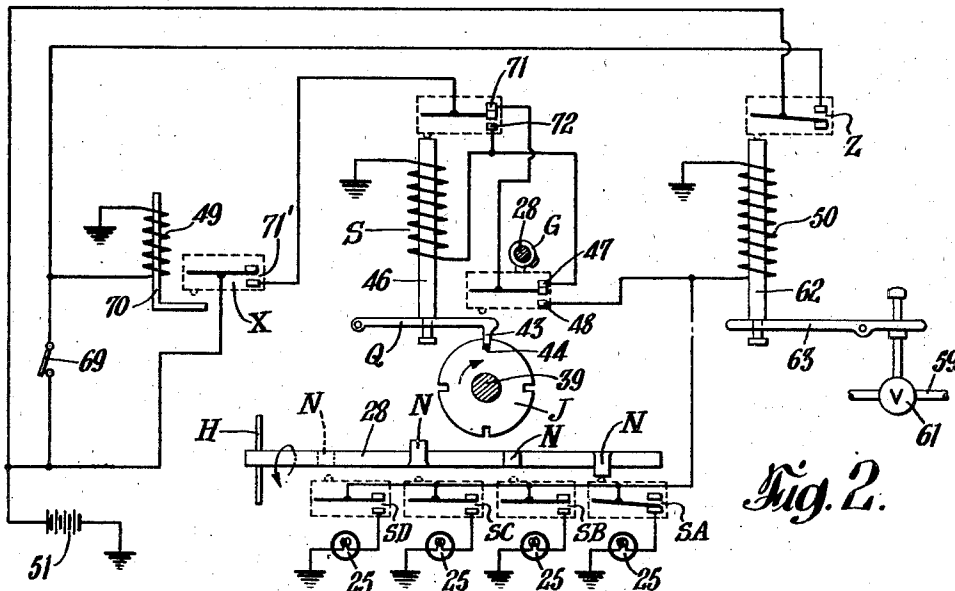
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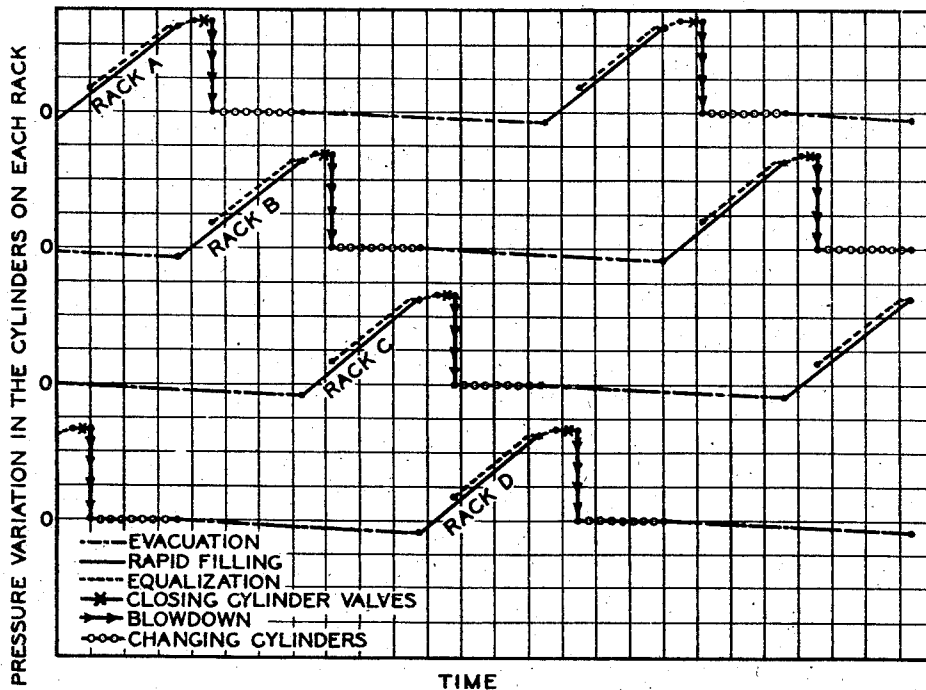
APPARATUS AND METHOD FOR FILLING GAS STORAGE CYLINDERS

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5 Sheets-Sheet 2



AUTOMATIC CHARGING EQUIPMENT CYCLE - TOPPING OFF WITH RISING PRESSURE



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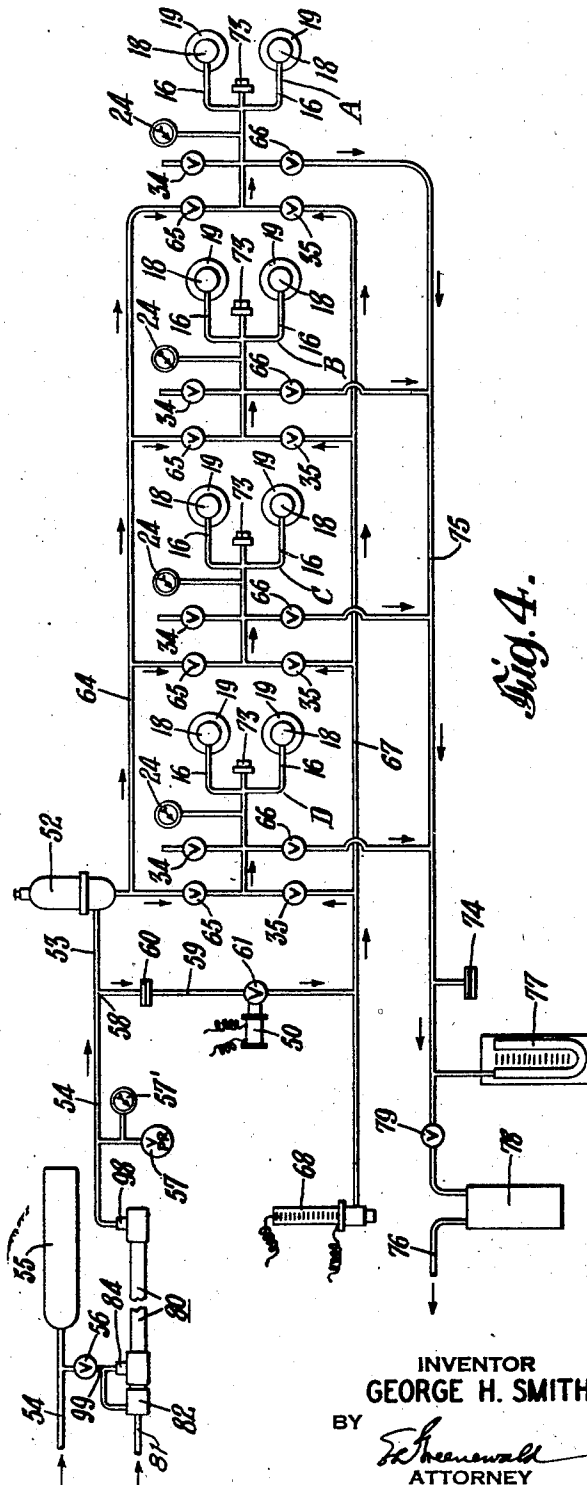
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APPARATUS AND METHOD FOR FILLING GAS STORAGE CYLINDERS

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Nov. 19, 1946.

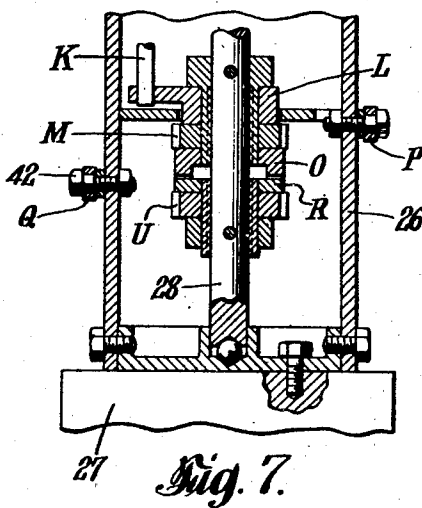
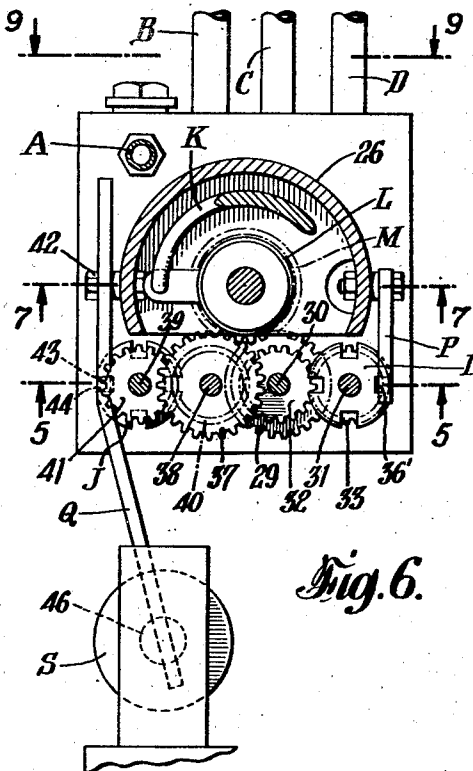
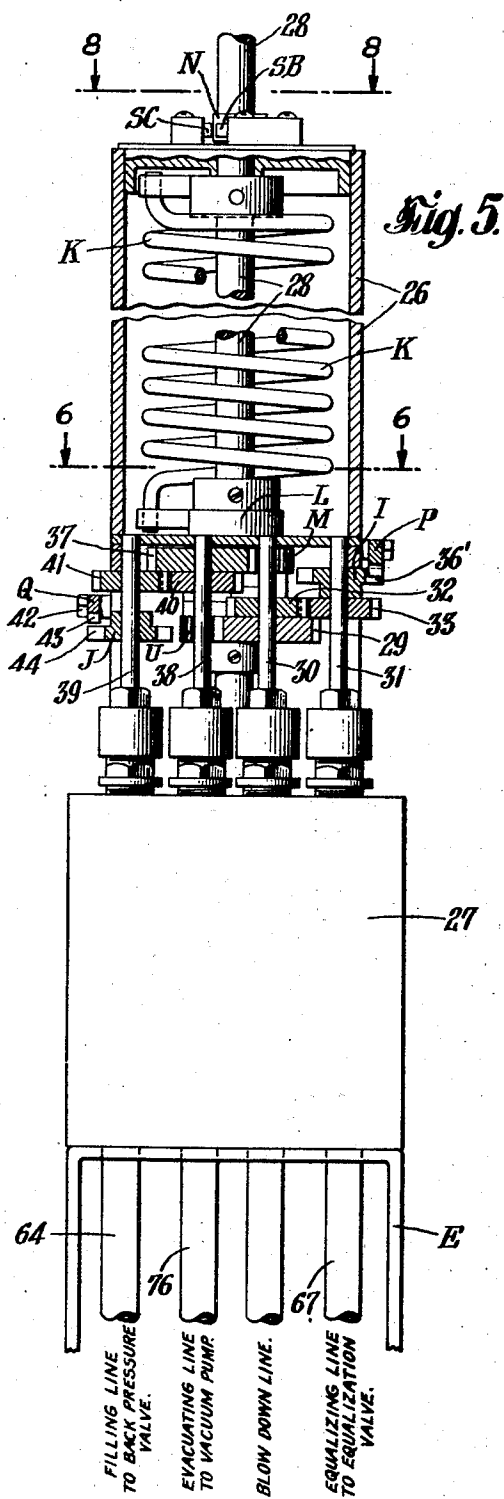
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APPARATUS AND METHOD FOR FILLING GAS STORAGE CYLINDERS

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5 Sheets-Sheet 4



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APPARATUS AND METHOD FOR FILLING GAS STORAGE CYLINDERS

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5 Sheets-Sheet 5

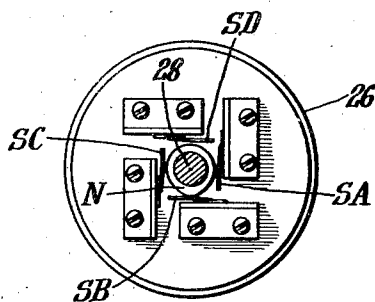


Fig. 8.

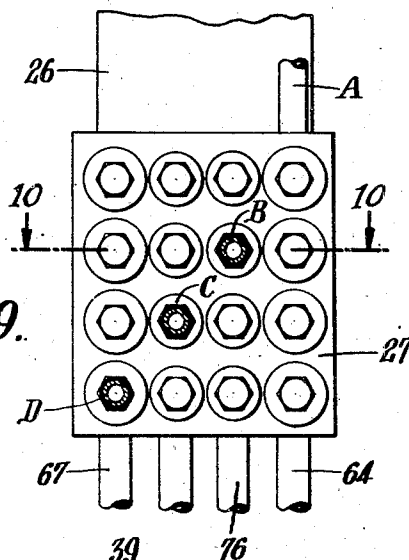


Fig. 9.

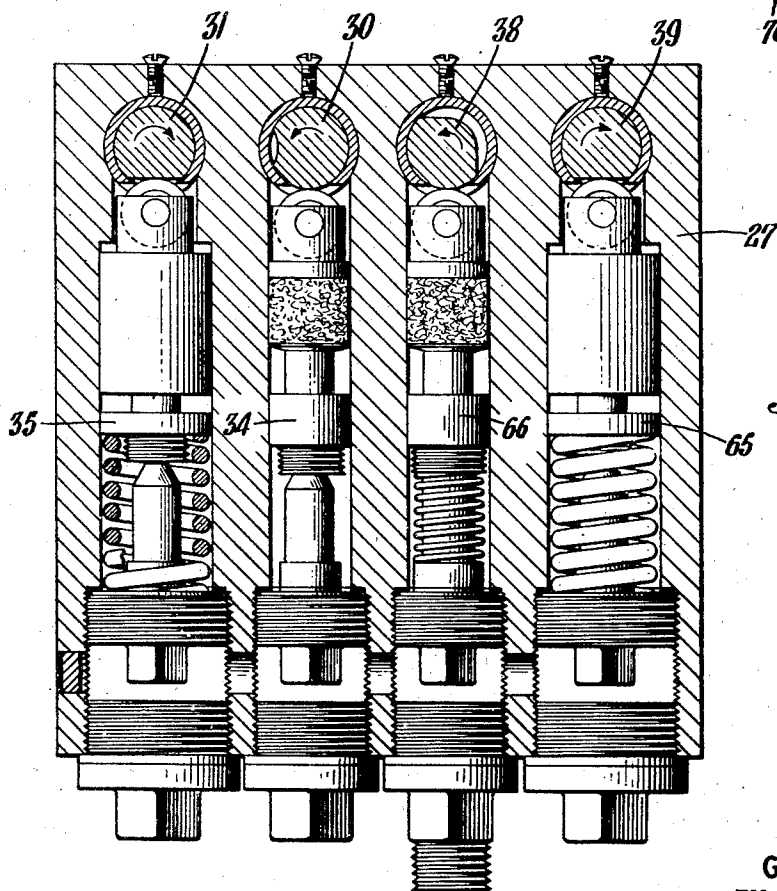


Fig. 10.

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UNITED STATES PATENT OFFICE

2,411,235

APPARATUS AND METHOD FOR FILLING
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Application February 11, 1943, Serial No. 475,567

15 Claims. (Cl. 226—20.1)

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This invention relates to a method of and apparatus for charging gas storage containers and more particularly to filling gas storage cylinders to a desired final pressure with valuable gas material, such as oxygen, nitrogen, hydrogen, helium, argon, or the like.

The main object of the invention is to provide apparatus for filling gas storage cylinders that is compact and so light in weight that it may be mounted on a mobile unit, such as an automotive truck which is adapted to transport the gas material in the liquid phase to the station at which the gas storage cylinders are to be filled. Another object of the invention is to provide an improved system for first evacuating and then filling cylinders including equipment that is substantially automatic in its operation and in which the cylinders are connected to be filled and disconnected after being filled in a sequence such that the maximum efficiency of the equipment and of an operator is obtained.

A further object is to provide an improved method of filling gas storage cylinders to a desired final pressure.

The invention comprises a four-rack two-cylinder system having a capacity of at least 100 cylinders per hour. Such system comprises simple and reliable means for filling any number of cylinders to the correct settled pressure and which is capable of carrying out the operation at a rate equivalent to the output rate of a high pressure liquid pump. In order to charge all of the cylinders within a predetermined range of a desired final pressure, the present invention contemplates a procedure termed a topping off cycle with a slowly changing pressure, whereby, for example, a small volume of gas is added to the cylinders at a comparatively low rate of flow after they have been charged rapidly to a pressure near, such as slightly below, the desired final pressure.

In general, according to the invention, the gas storage cylinders are filled progressively in pairs, the operating cycle of the system being such that, while four cylinders are being evacuated, two are being filled and two are being changed. There is, however, some overlapping of these operations.

Referring to the drawings:

Fig. 1 is a perspective view of a four-rack two-cylinder unit for charging gas storage cylinders with gas material, embodying the invention;

Fig. 2 is a circuit diagram of the electrical control system;

Fig. 3 is a graphical representation of the timing operations involved in filling gas storage cylinders according to the invention;

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Fig. 4 is a flow diagram illustrating the invention;

Fig. 5 is a fragmentary view partially in front elevation and partially in vertical section of the valve timing mechanism, taken on line 5—5 of Fig. 6;

Fig. 6 is a fragmentary view partially in top plan and partially in horizontal section, taken on line 6—6 of Fig. 5;

Fig. 7 is a fragmentary view in vertical section, taken on line 7—7 of Fig. 6;

Fig. 8 is a fragmentary view mainly in top plan, taken on line 8—8 of Fig. 5;

Fig. 9 is a fragmentary view mainly in rear elevation, taken on line 9—9 of Fig. 6; and

Fig. 10 is a fragmentary view in horizontal section, taken on line 10—10 of Fig. 9.

Referring to Fig. 1 of the drawings, the illustrated four-rack two-cylinder unit comprises a metal frame 10 adapted to be mounted on a suitable vehicle, such as an automobile truck, although the apparatus is not restricted to use in a mobile cylinder charging unit. The frame 10 consists of metal sections which are welded together to form a light-weight structure generally in the shape of an open rectangle having a base 11, uprights 12 and 13, and sides 14, 14. Supported by a bracket 15 on the top of the frame 10 are four gas manifolds or racks A, B, C and D, each of which is provided with a pair of flexible metal tubing "pigtaills" 16. Each "pigtail" terminates in a quick connector 17 for connection to the valve fitting 18 (Fig. 4) at the top of a conventional gas storage container 19 such as a cylinder in which oxygen in the gas phase is usually stored at an initial gas pressure of a predetermined value.

Laterally projecting members 20, 21 and 22 are mounted on the sides 14 of the frame 10 to locate the cylinders 19 in pairs on opposite sides of the frame, as indicated by the stations or places 23 corresponding to the racks A, B, C and D. Each of the racks is provided with a gas pressure gauge or indicator 24 mounted thereon. Also mounted on each rack is an electric signal lamp 25 for indicating when the cylinders connected to the rack are filled with gas at the desired final pressure.

In about the center of the frame 10, between the sides 14, 14 thereof is mounted a cylindrical housing 26 on a box 27 which is, in turn, supported by a bracket E. A main operating shaft 28 having a handle H, extends down through the center of a heavy main spring K (Fig. 5) in the form of a coil within the housing 26, the upper

end of the spring being connected to the shaft 28, and the lower end being connected to a collar L which is keyed to a gear M and the top half O (Fig. 7) of a clutch loosely mounted on the shaft 28. The lower half R of the clutch is keyed to a gear U which is pinned to the shaft 28, so that the lower half R of the clutch rotates whenever the shaft is turned. Such gear U meshes with a similar gear 29 on a blowdown valve stem 30 which is geared to an equalization valve stem 31 by gears 32 and 33, so that these two stems rotate, changing blowdown valves 34 and equalization valves 35 (Fig. 4) in the box 27 from one rack to another (there being a blowdown valve 34 and an equalization valve 35 for each of the racks A, B, C and D) whenever the spring shaft 28 is rotated.

A latch P pivoted to one side of the housing 26 and urged downwardly by a tension spring 36 engages a slot 36' in a collar I pinned to the equalization valve stem 31, every 90 degrees of rotation, thus locking the spring shaft 28 in position. The latch P is adapted to permit the shaft 28 to be advanced clockwise but not counter-clockwise. The gear M which is keyed to the upper half O of the clutch meshes with a gear 37 pinned to an evacuation valve stem 38 which is geared to a filling valve stem 39 by gears 40 and 41, so that such valve stems rotate when a latch Q restraining the spring force is released and the lower end only of the spring K is allowed to turn. The latch Q is pivoted at 42 to one side of the housing 26 and is provided with a projection 43 adapted to engage a slot 44 in a collar J attached to the filling valve stem 39, under the influence of a tension spring 45, connected at one end to the latch Q and at the other to the frame base 11.

The clutch is constructed so that the lower half R can be rotated 90 degrees in a clockwise direction while the top half O is locked in a stationary position by the latch Q, an operation which is performed at the end of a cylinder topping off period. When the latch Q is released at the end of a rapid cylinder filling period, the force of main spring K then causes the upper half of the clutch also to rotate 90 degrees in a clockwise direction, thus bringing the two halves O, R of the clutch assembly back to their original positions. The latch Q is adapted to be lifted out of engagement with the collar J by an armature 46 (Fig. 2) of a solenoid S when the latter is energized.

The main spring shaft 28 is also provided with a cam N mounted above the housing 26 (Fig. 8) for operating normally-open signal light contacts SA, SB, SC and SD. These contacts are simple micro-switches mounted on the top of the cover of the housing 26, which are operated by the force of the cam N when the shaft 28 is turned. Also connected to the shaft 28 is a cam G (Fig. 2) for closing electrical contacts 47 and opening electrical contacts 48, thereby de-energizing a solenoid 49 and a solenoid 50 (Fig. 2), to reset the electrical circuit when the handle H is moved through a 90 degree arc. A battery 51 is mounted within the bracket E, and provides a source of electrical energy for such circuit, although the battery of the vehicle on which the frame 10 is carried may be and preferably is used instead for this purpose.

Mounted in the upright 13 near the base 11 of the frame 10 is a back-pressure valve 52 the inlet of which is connected to a source of gas material at constant temperature under high pres-

sure by a pipe 53. Such source may be gaseous oxygen produced by conversion of liquid oxygen to the gas phase by a high-pressure pump and vaporizer apparatus the outlet of which is connected to a filling line 54 (Fig. 4) having an accumulator 55 connected thereto by a valve 56. Also connected to the filling line 54 is a high-pressure safety valve 57 and a high-pressure gauge 57'. The line 54 is connected to a Y-fitting 58 one branch of which is connected to the pipe 53 and the other branch of which is connected to a pipe 59 containing a metering orifice 60, such as a valve, and a shut-off valve 61 which is operated by the solenoid 50 (Fig. 2), the armature 62 of the latter being operatively connected to the valve 61 by a lever 63.

The outlet of the back-pressure valve 52 is connected by a pipe 64 to four filling valves 65 (Fig. 4) within the box 27 (Fig. 10) which are operated in sequence by rotation of the filling valve stem 39 through a suitable cam device, each valve 65 controlling the flow of gas to a rack. Each rack is also provided with an evacuation valve 66 in the box 27, which is operated by a cam device upon rotation of the stem 38.

The four equalizing valves 35 are connected between the racks and an equalizing line 67 (Fig. 4) to which the pipe 59 is also connected. A gas-pressure gauge 68 is connected to the line 67 and is provided with a column of mercury which is adapted to engage a contact when the gas pressure in the line 67 reaches a predetermined value to close a switch 69 (Fig. 2) and thereby cause the solenoid 49 to be energized. The solenoid 49 has an armature 70 adapted, when raised, to close a small micro-switch X having a contact 71' which is in circuit relation with the battery 51, normally-closed contacts 71 and 47, and solenoid S. The armature 46, when lifted, opens contacts 71 and 47, and closes contacts 72 which are in holding circuit relation with solenoid S, as well as contacts 48 which are in circuit relation with the solenoid 50 and battery 51. The armature 62, when raised, is adapted to close the valve 61, and close contacts Z in holding circuit relation with the battery 51 and solenoid 49, solenoid 50, and one set of the signal lamp contacts SA.

A rack safety device 73 is connected to each rack and is adapted to open should the gas pressure within a rack exceed a certain value in excess of that desired in the filled cylinders. A bursting disc 74 is also connected to an evacuation line 75 which is connected to each of the evacuation valves 66 and to a vacuum line 76 which communicates with any suitable evacuating means such as a vacuum pump. A mercury manometer 77 and a lubricant trap 78 are also connected to the vacuum line 76, with a valve 79 therebetween.

An automatic temperature controlling device 80 is associated with the gas supply or filling line 54 for the purpose of maintaining the temperature of the gas delivered to the cylinders 19 at a substantially constant value. The device 80 comprises a cold-liquid or cold-gas inlet 81 connected to a valve body 82 to which is connected a hot-gas inlet 84. Gas leaves the device 80 by way of a gas outlet 98.

Assuming that the device 80 is adjusted to a desired value of temperature, the device automatically operates to maintain the temperature of the gas leaving the outlet 98 substantially constant at such value.

In operation, assuming that eight cylinders 19

are connected to the apparatus, two on each of the four racks A, B, C and D, the operating cycle generally is such that the cylinders are filled in pairs, there being pairs of cylinders on either side of the unit as indicated in Fig. 1. The charging is done in such manner that the operator works progressively around the frame 10 in a clockwise direction. Briefly, the manual operations consist of:

(1) Closing two cylinder valves immediately after a signal light 25 flashes;

(2) Turning the operating handle H in an arc of 90 degrees so that the handle H is above the cylinder valves just closed, and

(3) Disconnecting the filled pair of cylinders from the rack and replacing them with empty cylinders. The operator then steps to the next pair of cylinders, in a clockwise direction, and repeats the above operations when the next signal lamp 25 lights.

As shown by Fig. 3, each pair of cylinders connected to the apparatus is subjected to the following operations which are described, for example, for filling oxygen cylinders of the customary size: The cylinders are evacuated, filled, topped off, and then removed from the rack. Rapid filling of the cylinders is accomplished at a constant rate which is such that many cylinders can be filled per hour. As soon as one pair of cylinders has been rapidly filled to a predetermined pressure, the filling of another pair is started. Since the filling can be accomplished in one-half the time required for evacuation, two pairs of cylinders are filled while one pair is being evacuated. The timing of these operations is shown graphically in Fig. 3, where the operations carried out simultaneously with respect to the four racks are also indicated. As shown by such graph, while one pair of cylinders is being rapidly filled, a second pair is completing its final period of evacuation, a third pair is completing its initial period of evacuation, and the fourth pair is being topped off and replaced with empty cylinders.

In the apparatus shown in the drawings the method of topping off the cylinders is accomplished by bleeding a small quantity of gas into the cylinders after the filling control valve has been closed, control of the final pressure being accomplished with a slowly rising cylinder pressure.

The actual manual operations in the present method of filling gas storage cylinders do not require more than a short time to carry out. Therefore, after the cylinders have been changed, there is a shorter period when no manual work is being done. During this time, the operator is free to inspect the cylinders. After an operator has become familiar with the apparatus, such inspection period may be increased.

It should be noted that there are four valves 34, 35, 65 and 66 (Fig. 4) for each of the four cylinder racks A, B, C and D. These sixteen valves are geared and mechanized in pairs (Figs. 5, 6 and 10) so that when rapid filling has been completed on rack A, its filling valve 65 is closed simultaneously with the closing of the evacuation valve 66 on rack B. The filling valve 65 then opens to rack B simultaneously with the opening of the evacuation valve 66 to rack D while the evacuation valve to rack C remains open. The cylinders on rack A which have just completed their rapid filling period are then being topped off. The gas material for topping off flows through the electric shut-off valve 61 because the

pressure on the inlet side of this valve 61 is maintained higher than the cylinder pressure at all times by the back-pressure valve 52. The rate of flow through the shut-off valve 61 into the cylinders 19 is maintained at a low value by the orifice 60 in the pipe 59.

During the topping-off operation the pressure inside the cylinders 19 is nearly equal to that in the rack because the rate of flow through the cylinder valves is comparatively low. When the mercury column in the gas pressure gauge 68, which is attached to the discharge side of the shut-off valve 61, increases to a certain height, it makes an electrical contact with an adjustable pointer located inside of the mercury column, which is conventionally shown in Fig. 2 as a normally-open switch 69. Closure of the switch 69 results in the closure of the shut-off valve 61, stopping all gas flow into the two cylinders being topped off; and the energization of the corresponding signal light 25. The operator then closes the two cylinder valves and turns the operating lever H which: (a) closes the equalizing valve 35 to rack A; (b) opens momentarily the blowdown valve 34 of rack A; (c) opens the equalizing valve 35 and the shut-off valve 61 to rack B; (d) cocks the main spring K within the housing 26 subsequently to operate the filling and evacuating valves 65 and 66; and (e) resets the electric circuit as shown in Fig. 2.

After the above operations have been carried out, the gas pressure gauge 68 registers the pressure in rack B, the cylinders on which are now being filled at a high rate of flow. As the cylinders connected to rack B are charged, the rack pressure rises rapidly, and when the mercury column again reaches the electric contact point (closing switch 69) another electrical circuit is completed which releases the main operating spring K, causing the filling valve 65 to rack B to close simultaneously with the closing of the evacuation valve 66 for rack C. This process is repeated for each of the four racks in rotation until the desired number of cylinders has been charged.

Assuming that eight cylinders 19 are connected to the apparatus, that the system is in continuous operation, and that the empty cylinders have just been attached to the rack D, the following conditions exist:

(1) The cylinders connected to the rack A are being charged rapidly through both the filling and equalizing valves 65 and 35;

(2) The cylinders connected to rack B are in the second period of being evacuated and are the next to be filled;

(3) The cylinders connected to rack C are in the first period of being evacuated;

(4) The cylinders connected to the rack D are idle;

(5) The operator is standing in front of the cylinders connected to the rack A waiting until the filling of these cylinders is completed. This will be indicated when the red lamp 25 connected to the rack A is illuminated.

During the charging of the cylinders connected to the rack A, the mercury column in the gas pressure gauge 68 rises, indicating the pressure in rack A, since the gauge 68 is attached to the piping 67 on the rack side of the electric shut-off valve 61. When the top of the mercury column reaches the metallic pointer which extends down into the glass tube from the top, the switch 69 is closed. This closes the relay circuit which energizes the solenoid S, Fig. 2. When this solenoid S is energized, the armature 46 is lifted, releas-

ing the latch 43 on the lever Q from the slot 44 in the filling valve stem collar J. Since the filling valve stem 39 is geared to the evacuating valve stem 38, which in turn is geared to the shaft 28 of the main operating spring K, releasing the latch 43 allows the filling and evacuating valve stems 39 and 38 to rotate 90 degrees, thus closing the filling valve 65 to rack A and opening the filling valve 65 to rack B, as shown in Fig. 3. Rapid charging of the cylinders connected to the rack B is then begun.

The 90 degree rotation of the evacuating valve stem 38 causes the evacuation valve 66 to rack B to close, and opens the evacuation valve 66 to rack D. The evacuating valve 66 to rack C remains open during such operation.

As the rapid filling of the cylinders connected to the rack B begins, the cylinders connected to the rack A are being topped off. This is accomplished by allowing the gas material to flow slowly into the cylinders through the electric shut-off valve 61 and the equalizing valve 66 of the rack A, as shown in the flow diagram, Fig. 5. Since the gauge 68 still registers the pressure in rack A, the mercury column drops somewhat below the contact point after the filling valve 65 is closed because the rack pressure equalizes with the lower pressure in the cylinders. During rapid charging the cylinder pressure is lower than the rack pressure by an amount equal to the pressure drop across the cylinder valves and pigtail 16. As the gas flows into the rack B through the electric shut-off valve 61, the mercury column again rises slowly until it touches the contact pointer a second time. This second contact or closure of switch 69 results in the energization of the solenoid 50, Fig. 2, which closes the electric valve 61 in the equalizing line 59, and in addition, energizes the signal light 25 on rack A, indicating that the topping off of the cylinders connected to rack A has been completed.

When the signal light 25 connected to rack A flashes, the operator performs the following operations:

- (1) Closes the valves on the cylinders connected to rack A;
- (2) Pulls the operating lever H, Fig. 1, through an arc of 90 degrees to a new position such that the lever H is over the cylinders connected to rack A;
- (3) Disconnects the cylinders from rack A and replaces them with empty cylinders.

The operator then moves to a position in front of the cylinders connected to rack B and waits until the light 25 on that rack flashes, following which he again performs the operations set forth above.

The automatic operation of the equipment results from the following three steps:

- (1) First contact of the rapidly rising mercury column with the pointer inside the glass tube;
- (2) Second contact of the slowly rising mercury column with the pointer inside the glass tube;
- (3) Manual operation of the handle H through 90 degrees.

The automatic operations resulting from each of such steps are described below:

After the operating lever H has been rotated through 90 degrees, one pair of cylinders is being filled rapidly through both the filling and equalizing lines. At this time, the electric circuit, which preferably operates at a certain potential, is in the condition indicated by Fig. 2. When the mercury column rises to a point where it touches the

contact (switch 69) inside the tube, the switch 69 is closed, thereby energizing solenoid 49. The action of this solenoid operates the small micro-switch X, closing contact 71', which energizes solenoid S through the closed contacts 71 and 47. The operation of the armature 46 lifts the lever Q which releases the cam shaft collar J and allows the filling and evacuating valve stems to turn through 90 degrees by spring action.

The operation of solenoid S also causes the contacts 71 and 47 to open, and closes contacts 72 and 48. The solenoid S is then energized through the contacts 72. When the mercury falls away from the pointer (switch 69), the contacts or switches 69, 71' and 72 are opened while contact 48 remains closed until cam G is manually operated by means of shaft 28 and handle H to open switch 48 and close switch 47; contact 71 is closed; solenoids 49 and S are de-energized, and the projection 43 on the latch Q falls into the next slot 44 in the collar J.

After the operations described above, two new cylinders are being charged rapidly through the filling line and the two cylinders just filled are being topped off through the shut-off valve and equalizing line. As these cylinders are being topped off, the mercury column again rises slowly until it again touches the pointer in the glass tube, thus closing the switch 69 a second time. This again energizes solenoid 49, closing contact 71' and energizing solenoid 50 through the closed contacts 71 and 48. The armature 62 of solenoid 50 then closes the shut-off valve 61, stopping all flow of gas into the cylinders and terminating the topping off period.

As the solenoid 50 is energized, one of the four signal lights 25 is also energized through the switch SA, which is being held closed by the cam N on the main spring shaft 28 (this shaft 28 is rotated manually later, after the cylinders are closed off). Also, as solenoid 50 energizes, the contact Z is closed. This causes the solenoids 49 and 50 and the signal light to remain energized even though the mercury column falls away from the pointer inside of the glass tube, opening the switch 69.

When the signal light 25 flashes, the cylinder valves are first closed off and then the operating lever H must be rotated clockwise through 90 degrees. Such rotation of this lever H performs the following operations:

- (1) Turns the main operating shaft 28, which extends down through the center of the heavy coil spring K within the housing 26, Fig. 1. Since the upper end of the spring is pinned to the shaft 28, and the lower end is being held rigidly in place through the filling and evacuating valve gearing by the latch Q on the slotted collar J, the main spring is cocked as the shaft 28 is turned. The latch P, which falls into the slotted collar I on the equalizing valve cam shaft 31 locks the spring shaft 28 in the new position.

(2) Rotates through 90 degrees the blowdown valve cam shaft 30, which is directly geared to the spring shaft 28, thus blowing down the pressure in the rack just filled, to the atmosphere, relieving this pressure before the cylinders are removed from the rack. This safety feature prevents deformation of the pigtail connections, such as would occur with high pressure in the rack, when the couplings are quickly detached from the cylinders.

(3) Rotates the equalizing valve cam shaft 31, which is geared to the blowdown valve cam shaft 30, through 90 degrees, thus closing the equaliz-

ing valve 35 to the full rack and opening such valve to the rack being filled.

(4) Opens the signal light contacts SA, Fig. 2, on the rack just filled and closes the signal light contacts SB to the next rack.

(5) Closes the electrical contacts 47 by means of the cam G, and opens the electrical contacts 48, thereby deenergizing the solenoids 49 and 50. This opens contacts 71' thus resetting the electric circuit so that all contacts are again as shown in Fig. 2, except that the contacts SB are closed and contacts SA are open. The shut-off valve 61 to the equalization line 67 is then open to the next rack being filled.

The arrangement of gears between the main operating spring shaft and the four valve stems is shown in Figs. 1, 6, 7 and 8. At the end of each topping off period the lower half R of the clutch is rotated whenever the spring shaft 28 is turned through 90 degrees. Since the blow-down and equalization valve stems are geared together, these two stems rotate, changing the valves from one rack to another, whenever the spring shaft is rotated. The latch P engages a slot on the collar pinned to the equalization valve stem every 90 degrees of rotation, thus holding the spring shaft 28 in position. The latch P is such that the shaft 28 can be turned clockwise but not counter-clockwise, as pointed out above. Since the evacuation and filling valve stems are geared directly together, these two stems will rotate when the latch restraining the spring force is released and the bottom end of the spring only is allowed to turn. The position of the latch Q, in the slotted collar J, attached to the filling valve stem is shown in Fig. 2.

The clutch within the housing 26 is constructed such that the lower half R can be rotated 90 degrees in a clockwise direction while the top half O is located in a stationary position by the latch Q. This is the operation which is performed when the operating lever H is turned through 90 degrees at the end of the topping-off period. When the latch Q is released at the end of the rapid filling period, the spring force then causes the upper half of the clutch also to rotate 90 degrees in a clockwise direction, thus bringing the two halves O, R of the clutch assembly back to their original positions.

The apparatus is compact and entirely suitable for mobile use, the valve assembly including the sixteen valves being located in the box 27. For safety reasons all parts in contact with oxygen gas are made of non-combustible materials. Thus, all materials used in the construction of the valve assembly are preferably metals except the valve stem packing which is preferably asbestos and graphite. At the same time the apparatus is sufficiently compact and of such light weight that it may be mounted on a mobile pumping unit. The novel topping-off operation results in a substantially uniform final pressure in the filled cylinders.

The topping-off period which follows immediately after the cylinders have been rapidly charged to a predetermined pressure permits the gas to flow slowly into the cylinders until the correct pressure is obtained. This relatively slow rate of flow reduces the errors caused by varying time lags in the valve operating mechanism and the differences in final cylinder pressures resulting from variation in the pressure drop through the cylinder valves at high rates of flow.

What is claimed is:

1. Apparatus for filling gas storage cylinders 75

comprising, in combination, a plurality of cylinder racks, cylinder evacuating means including means for selectively connecting at least two of said racks to a vacuum pump; cylinder filling means including means for selectively connecting at least one of said racks to a source of gas material under pressure; rack blowdown means including means for selectively opening at least one of said racks to the atmosphere; automatic rack shut-off means for closing communication between a rack and said source of gas material when a desired final cylinder pressure is reached; full-cylinder indicating means including a signal for each of said racks for indicating when the desired cylinder pressure is reached; and control means adapted, when actuated, to operate said blowdown means to release gas from the proper rack, to shift said cylinder evacuating means from one rack, and to shift said cylinder filling means to said last-named rack; said racks being arranged so that at least one filled cylinder may be replaced by at least one empty cylinder on each rack, following each actuation of said control means, in a predetermined sequence.

2. Apparatus for filling gas storage cylinders to a desired final pressure comprising, in combination, a plurality of cylinder racks, cylinder evacuating means including means for selectively connecting at least two of said racks to a vacuum pump; cylinder filling means including means for selectively connecting at least one of said racks to a source of gas material the pressure of which is greater than the desired cylinder pressure, comprising a constant-temperature controlling device adapted to be connected to said source, a relatively high-capacity connection including a back-pressure valve between said device and said rack for initially charging at least one cylinder connected to said rack with said gas material at a very rapid rate until the cylinder pressure reaches a value near the desired final pressure, and a relatively low-capacity connection for finally causing the gas material to flow at a very slow rate until the cylinder pressure reaches the desired value; rack blowdown means including means for selectively opening at least one of said racks to the atmosphere; automatic rack shut-off means for closing communication in said low-capacity connection between a rack and said source of gas material when a desired final cylinder pressure is reached; full-cylinder indicating means including a signal for each of said racks for indicating when the desired cylinder pressure is reached; and control means adapted, when actuated, to operate said blowdown means to release gas from the proper rack, to shift said cylinder evacuating means from one rack, and to shift said cylinder filling means to said last-named rack; said racks being arranged so that at least one filled cylinder may be replaced by at least one empty cylinder on each rack, following each actuation of said control means, in a predetermined sequence.

3. Apparatus for filling gas storage cylinders comprising, in combination, a cylinder rack, cylinder evacuating means including means for connecting said rack to a vacuum pump; cylinder filling means including means for connecting said rack to a source of gas material under pressure; rack blow-down means including means for opening said rack to the atmosphere; automatic rack shut-off means for closing communication between said rack and said source of gas material when a desired final cylinder pressure is reached; full-cylinder indicating means including a signal

for said rack for indicating the operation of shut-off means; and common control means for operating said cylinder evacuating means to connect said rack to a vacuum pump, for operating said cylinder filling means to connect said rack to a source of gas material under pressure, and for operating said rack blowdown means to open said rack to the atmosphere, in response to each actuation of said common control means.

4. Apparatus for filling gas storage cylinders as claimed by claim 3, wherein said means for connecting said rack to a source of gas material under pressure comprises a relatively high-capacity connection for initially charging a cylinder connected to said rack with said gas material at a very rapid rate until the cylinder pressure reaches a value slightly below the desired final pressure, and a relatively low-capacity connection for finally charging such cylinder with said gas material at a very slow rate until the cylinder pressure reaches the desired final value.

5. Apparatus for filling gas storage cylinders comprising, in combination, four-cylinder racks each having two flexible conduits terminating in quick connectors for connecting a pair of cylinders to each rack; cylinder evacuating means including means for selectively connecting any two of said racks to a vacuum pump; cylinder filling means including means for selectively connecting any one of said racks to a source of gas material under pressure; rack blowdown means for selectively opening any one of said racks to the atmosphere; a signal operatively associated with each of said racks for indicating when the cylinders connected thereto are filled with said gas material to a desired final pressure; and control means adapted, when actuated, to operate said blowdown means to release the gas from a rack to which a pair of suitably filled cylinders are connected, to shift said evacuating means from the rack to which a pair of evacuated cylinders are connected, and to shift said filling means to said last-named rack; said racks being arranged so that a pair of filled cylinders connected to each rack may be replaced by a pair of empty cylinders on each rack, following each actuation of said control means, in a predetermined sequence.

6. Apparatus for filling gas storage cylinders to a desired final pressure comprising, in combination, a cylinder rack; a constant-temperature controlling device having inlet means connected to a source of gas material the pressure of which is greater than the desired final cylinder pressure; a relatively high-capacity connection between said device and said rack for initially charging at least one cylinder connected to said rack with said gas material at a very rapid rate until the cylinder pressure reaches a value near the desired final pressure; and a relatively low-capacity connection between said device and said rack for finally causing the gas material to flow through said rack at a very slow rate until the cylinder pressure reaches the desired final value, said low-capacity connection being in parallel relation with said high-capacity connection.

7. Apparatus for filling gas storage cylinders to a desired final pressure comprising, in combination, a cylinder rack; a constant-temperature controlling device having inlet means connected to a source of gas material the pressure of which is greater than the desired final cylinder pressure; a relatively high-capacity connection including a back-pressure valve between said device and said rack for initially charging at least one cylinder connected to said rack with said gas

material at a very rapid rate until the cylinder pressure reaches a value slightly below the desired final pressure, and a relatively low-capacity connection between said device and said rack for finally causing the gas material to flow into said cylinder at a very slow rate until the cylinder pressure reaches the desired final value.

8. Apparatus for filling gas storage cylinders to a desired final pressure comprising, in combination, a cylinder rack; cylinder filling means including means for connecting said rack to a source of gas material under pressure which is greater than the desired final cylinder pressure; said connecting means comprising a relatively high-capacity connection for initially charging a cylinder connected to said rack with said gas material at a very rapid rate until the cylinder pressure reaches a value slightly below the desired final pressure, and a relatively low-capacity connection in parallel with said high-capacity connection for finally charging such cylinder connected to said rack with said gas material at a very slow rate until the cylinder pressure reaches the desired final value.

9. The method of evacuating and filling gas storage cylinders of the type having a cylinder valve, which comprises opening the cylinder valve and evacuating each cylinder while the cylinder valve remains open, rapidly charging each cylinder with gas from a source the pressure of which is substantially higher than a desired final pressure of the gas within the filled cylinder by a relatively high rate of gas flow through said cylinder valve until the pressure of the gas within said cylinder reaches a predetermined value which is slightly different from that of said desired final pressure; then, while the cylinder valve remains open, slowly changing the gas pressure within said cylinder by a substantially reduced rate of gas flow through said cylinder valve until the pressure of the gas within said cylinder reaches the desired value; and thereupon closing said cylinder valve.

10. The method of evacuating and filling gas storage cylinders as claimed by claim 9, in which rapid charging of the cylinder is stopped when the pressure of the gas within said cylinder reaches a predetermined value which is slightly below that of the desired final pressure and a small volume of gas is added to the cylinder at a comparatively low rate of flow immediately after it has been charged rapidly to said predetermined value.

11. The method of filling a number of gas storage cylinders which comprises connecting a pair of cylinders to each of four racks; opening the first and second racks to a vacuum pump; after the cylinders connected to said first and second racks are evacuated, substantially simultaneously closing said first rack to said vacuum pump, opening the third rack to said vacuum pump, and opening said first rack to a source of gas material under pressure; after the cylinders connected to said first rack are filled with said gas material to a desired final pressure, substantially simultaneously closing said first rack to said source of gas material, closing said second rack to said vacuum pump, opening the fourth rack to said vacuum pump, and opening said second rack to said source of gas material; replacing the filled cylinders on said first rack with empty cylinders; after the cylinders connected to said second rack are filled, substantially simultaneously closing said second rack to said source, closing said third rack to said vacuum pump, opening said first rack

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to said vacuum pump, and opening said third rack to said source; and repeating the last two steps for each rack until all of the cylinders have been filled with said gas material.

12. The method of filling a number of gas storage cylinders with gas material to a desired final pressure, which comprises connecting a plurality of cylinders to each of a plurality of racks; opening the first and second racks to a cylinder evacuating line; after the cylinders connected to said first rack are evacuated, substantially simultaneously closing said first rack to said evacuating line, opening the third rack to said evacuating line, and opening said first rack to a cylinder filling line; after the cylinders connected to said first rack are filled, substantially simultaneously closing said first rack to said filling line, closing said second rack to said evacuating line, opening the fourth rack to said evacuating line, and opening said second rack to said filling line; replacing the filled cylinders on said first rack with empty cylinders; and repeating the last two steps for each subsequent rack until all of the cylinders have been filled.

13. A four-rack two-cylinder method of filling a number of gas storage cylinders with gas material to a desired final pressure, which comprises, closing a first rack to a cylinder evacuating line to which a second rack is also opened, opening a third rack to said evacuating line, and opening said first rack to a cylinder filling line; closing said first rack to said filling line, closing said second rack to said evacuating line, opening a fourth rack to said evacuating line to which said third rack is also opened, and opening said second rack to said filling line; replacing the filled cylinders on said first rack with empty cylinders; closing said second rack to said filling line, closing said third rack to said evacuating line, opening said first rack to said evacuating line, opening said third rack to said filling line, closing said second rack to said evacuating line, opening said fourth rack to said evacuating line to which said first rack is also opened, and opening said fourth rack to said filling line; replacing the filled cylinders on said third rack with empty cylinders; closing said fourth rack to said filling line, closing said first rack to said evacuating line, opening said third rack to said evacuating line to which said second rack is also opened, and opening said first rack to said filling line; replacing the filled cylinders on said fourth rack with empty cylinders, and repeating such cycle until all of the cylinders have been filled.

14. A four-rack two-cylinder system for filling gas storage cylinders with gas material to a desired final pressure, comprising a cylinder filling line having an inlet end adapted to be connected to a source of gas material the pressure of which is greater than the desired final cylinder pressure, said filling line containing an automatic gas temperature controlling device for maintaining at a substantially constant value the temperature of the gas delivered by said filling line, a gas accu-

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mulator connected to said filling line, a back-pressure valve in said filling line; four racks each having two cylinder connections, means including a filling valve connecting each of said racks to said back-pressure valve, a rack blowdown valve connected to each rack, a gauge for indicating cylinder pressure, an equalizing line connected to said gauge, means including a metering orifice and a shut-off valve connecting said equalizing line to said filling line, means including an equalizing valve connecting each rack to said equalizing line, a cylinder evacuating line adapted to be connected to a vacuum pump, means including an evacuation valve connecting each rack to said evacuating line, and means connecting said filling, blowdown, equalizing and evacuation valves for operation in pairs so that while one pair of cylinders is being rapidly filled, a second pair of cylinders is completing a final period of evacuation, a third pair is completing an initial period of evacuation, and the fourth pair is being topped off, the rack blown down, and the filled cylinders replaced with empty cylinders.

15. A four-rack two-cylinder system of filling gas storage cylinders with gas material to a desired final pressure, comprising four racks each having a pair of cylinder connections, a filling valve, an equalizing valve, an evacuation valve, a blowdown valve, and a full-cylinder signal lamp; a high-capacity cylinder filling line connected to the filling valves; a low-capacity cylinder filling line containing a shut-off valve connected to the equalizing valves; a cylinder evacuating line connected to the evacuation valves; a normally-open switch responsive to the pressure of said equalizing line and adapted to close when the cylinder pressure reaches a predetermined value, a main operating shaft having a handle; a coiled spring having one end connected to said shaft; a clutch having a first member loosely mounted on said shaft and connected to the other end of said spring, and a second member connected to said shaft; gear and cam means including stems for connecting the blowdown valves and the equalizing valves to said second clutch member; gear and cam means including stems for connecting the filling valves and the evacuation valves to said first clutch member; means for locking said equalizing and blowdown valve stems and said shaft against reverse rotation every 90 degrees by said spring; means including a latch for normally holding said filling and evacuation valve stems against forward rotation by said spring; means including a solenoid for releasing said latch to cause said spring to turn said filling and evacuation valve stems through 90 degrees; electric circuit means including said signal lamps, said switch and said solenoid for energizing said solenoid to release said latch when said switch is first closed and to close said shut-off valve and illuminate one signal lamp when said switch is again closed; and means including cam means connected to said shaft for resetting said electric circuit when said shaft is rotated through 90 degrees to cock said spring.

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