# United States Patent [19]

**McJones**

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[54] **CHARGING SEQUENCE SYSTEM AND PROCESS**


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[21] Appl. No.: **329,642**

**Related U.S. Application Data**

[60] Division of Ser. No. 92,814, Nov. 25, 1970, Pat. No. 3,719,196, which is a continuation-in-part of Ser. No. 34,966, May 6, 1970.

[52] **U.S. Cl.** ..... **137/12,** 137/110, 137/112, 137/119, 137/256

[51] **Int. Cl.** ..... **F17d 1/02**

[58] **Field of Search** ..... 137/12



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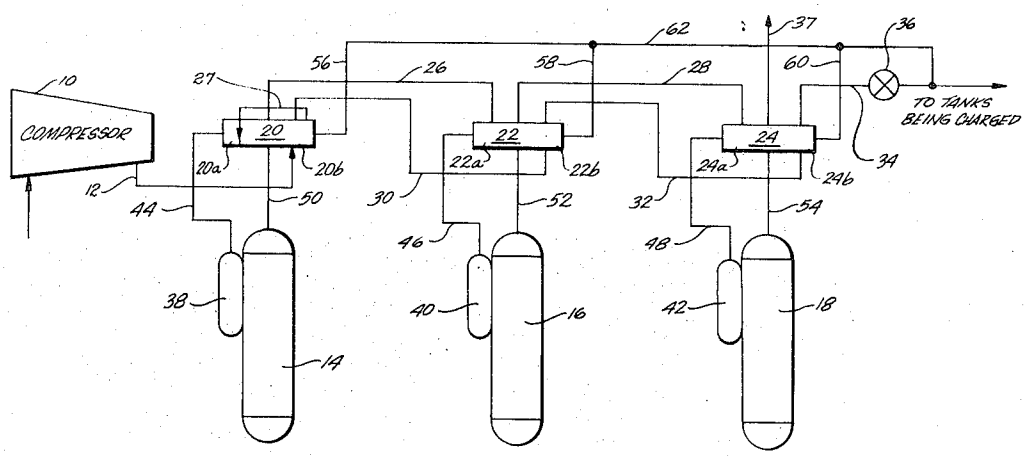
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*Attorney, Agent, or Firm*—Christie, Parker & Hale



[57] **ABSTRACT**

Each container in a bank of containers is individually charged with a gas in the order of the highest residual pressure remaining in the containers at the time charging is initiated. Gas withdrawal from the containers begins with the container at the lowest beginning pressure.


**2 Claims, 2 Drawing Figures**



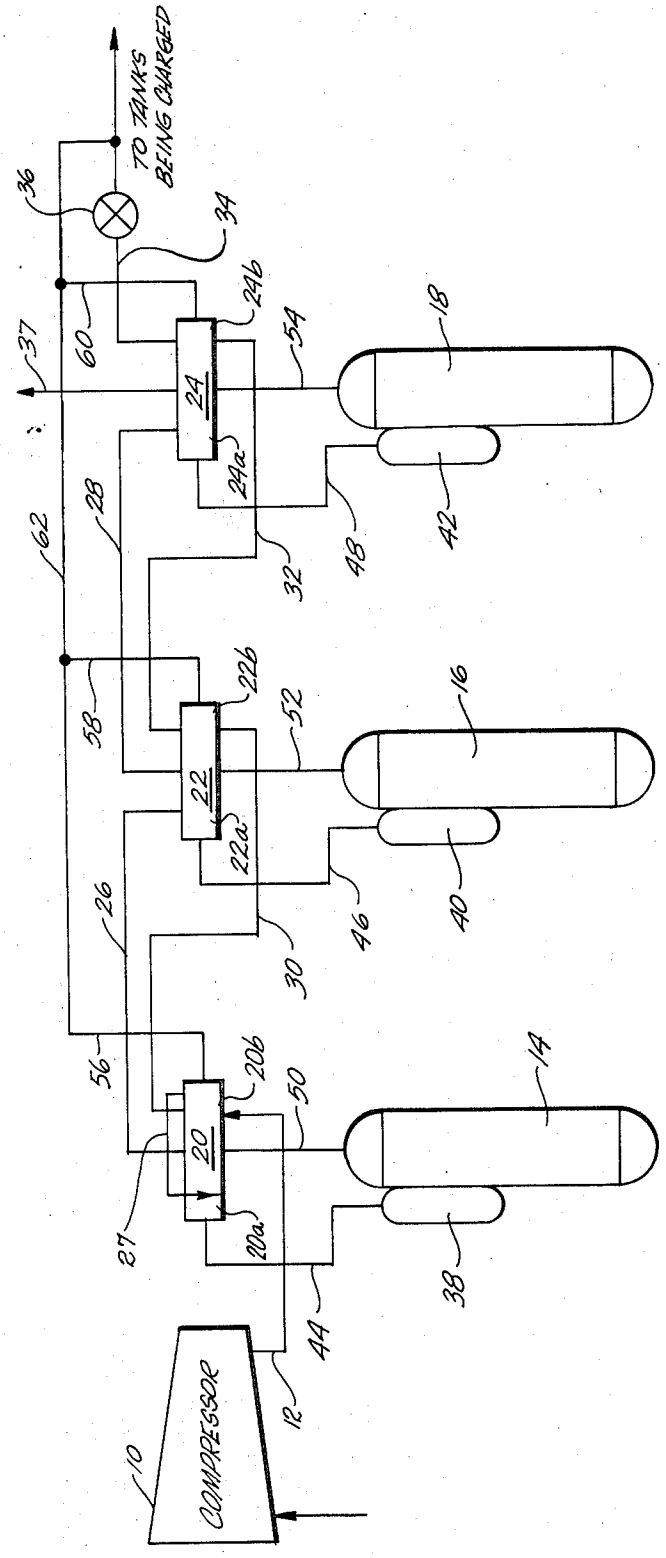

TO TANKS BEING CHARGED
36
34
37
60
24b
54
18
24
24a
28
62
32
48
42
58
22b
52
16
22
22a
26
30
46
40
56
20b
50
14
20
27
20a
38
44
12
10
COMPRESSOR

FIG. 1

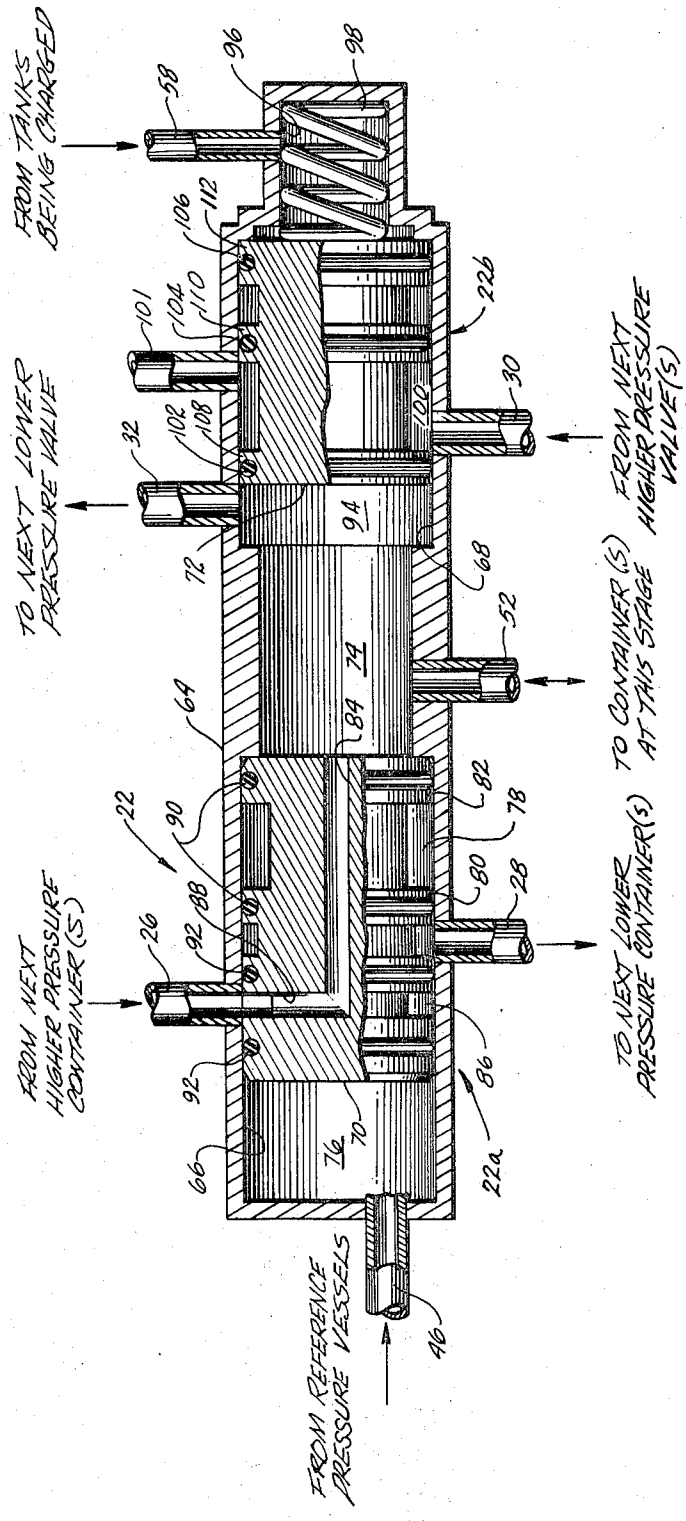

FROM TANKS BEING CHARGED
58
96
98
106
112
101
104
110
226
30
100
32
102
108
TO NEXT LOWER PRESSURE VALVE
FROM NEXT HIGHER PRESSURE VALVE(S)
72
94
68
52
TO CONTAINER(S) AT THIS STAGE
64
84
74
82
78
22
90
80
88
28
26
FROM NEXT HIGHER PRESSURE CONTAINER(S)
92
TO NEXT LOWER PRESSURE CONTAINER(S)
86
66
76
70
22a
FROM REFERENCE PRESSURE VESSELS
46

FIG_2

# CHARGING SEQUENCE SYSTEM AND PROCESS

## CROSS-REFERENCE TO RELATED APPLICATION

The present application is a division of U.S. Pat. application Ser. No. 92,814, filed Nov. 25, 1970, now U.S. Pat. No. 3,719,196, which in turn was a continuation-in-part application of U.S. Pat. application Ser. No. 34,966, filed May 6, 1970.

## BACKGROUND OF THE INVENTION

The present invention relates in general to the art of charging and withdrawing gas from containers. More specifically, the present invention relates to a charging system and process which effects sequential charging of a group of containers beginning with the container having the highest residual pressure before charging and ending with the container having the lowest residual pressure, and which effects sequential withdrawal beginning with the container having the lowest pressure before withdrawal commences and ending with the container having the highest pressure.

In the fight against air pollution it has become known that natural gas is an ideal fuel for internal combustion engines. This fuel substantially reduces the emission level of the pollutants of carbon monoxide, oxides of nitrogen and hydrocarbons over the emission levels experienced by gasoline.

Natural gas for use as a fuel in internal combustion engines can be stored in vehicles as a gas in suitable containers, often referred to as tanks or bottles. Typically, presently available tanks are rated at 2,265 p.s.i. at standard temperature conditions.

Obviously, the natural gas tanks in a vehicle must be recharged from time to time. The time to recharge tanks when a natural gas compressor is used alone is often too great for orderly refueling. As a consequence, it is necessary to augment compressor charging in some cases by the use of a storage bank of containers maintained, whenever possible, at some limiting high pressure. However, during large refueling demands on a refueling system it is not always possible to maintain the storage bank of containers at their maximum rated pressure.

Obviously, at any time it is highly desirable to charge a vehicle's natural gas tanks to the highest pressure possible within a given period of time.

## SUMMARY OF THE INVENTION

The present invention is directed to a charging system which will effect a rapid charging of a vehicle's natural gas tanks to the maximum pressure commensurate with the capacity of the fueling system and the short time requirements required for the efficient fueling of vehicles. In a more specific embodiment, the present invention contemplates the withdrawal of gas from the system for the maximum charging of the tanks.

More specifically, the present invention provides a process and system which employs at least two storage containers or vessels which are sequentially charged in the order of the highest residual pressure existing in a container before charging commences.

A specific form of the present invention contemplates a source of pressurized gas which may include a compressor, a series of containers to be charged, and sequence fill and transfer valve means for each container. The sequencer valve means each has a fill position and a transfer position. Means is provided for maintaining each sequencer valve means in its fill position and in communication with its container below a predetermined pressure, typically the rated pressure of the containers. Means is also provided for each sequencer valve means to change the valve's position from its fill position to its transfer position in response to the predetermined pressure existing in its associated container and to then establish communication between a downstream valve and the gas source. Means is also provided to prevent gas communication between a container and the source of pressurized gas when another container is being charged.

In a more specific form, the system of the present invention contemplates that each sequencer valve means control the flow of gas from the source of pressurized gas to succeeding containers in a series of containers by preventing gas communication beyond the valve means admitting to gas flow to its container. This may be done by connecting the source of gas to the containers in series through the sequencer valve means and providing each sequencer valve means with means for preventing gas flow downstream from it when it is admitting to gas flow into its container.

It is preferred that the means for maintaining each of the valves in its fill position until a predetermined pressure is reached be temperature compensated in order that utilization of available container volume be maximized. In greater detail, it is preferred that the temperature within a container being charged control the predetermined pressure to compensate for variations in container temperature owing to such factors as ambient temperature. Thus on a warm day where the density of a given amount of gas is low but its pressure relatively high, the predetermined pressure would be higher than the rated pressure of the container. Conversely, on a cold day for a given amount of gas, the predetermined pressure would be lower than the rated pressure of the container. This is detailed in copending application Ser. No. 34,966 of which this application constitutes a continuation-in-part.

The present invention also contemplates the selective charging of other vessels or containers from the storage containers by charging from the storage container having the lowest beginning pressure initially and ending at the storage container having the highest beginning initial pressure.

A preferred form of the sequencer valve means of the present invention contemplates the combining of the sequencer fill and transfer valve and a transfer sequencer valve. A valve spool for the fill and transfer sequencer valve is disposed in a bore of a housing for translation between a fill position and a transfer position. Inlet means to the bore is provided from an outlet means from the bore of the next sequencer valve upstream and from the source of gas for the first valve. The spool in the fill position masks the outlet means but communicates the particular valve's container with the inlet port. In the transfer position, the spool prevents communication from the inlet port to the container but allows communication through the valve to the next subsequent sequencer valve's inlet. The position of the spool is determined by pressure on a reference pressure side thereof and on a side in direct communication with its associated container such that when container pressure reaches the predetermined value it overcomes the

effect of the reference pressure and any biasing means to shift the spool to the transfer position.

On the withdrawal side of each valve a draw and bypass spool is provided, the position of which between a draw position and a bypass position is determined by its container pressure and a reference pressure. The reference pressure is the pressure of the tanks receiving gas from the container and, preferably, a biasing spring. In the bypass position of each valve, the valve's container is out of communication with the tanks but the tanks are in communication with the next upstream valve, or the source of gas in the case of the last valve. In the draw position of each valve, upstream valves are out of communication with the tanks but the container for the particular valve is in communication with the tanks. As a consequence, the lowest pressure containers will exhaust first.

These and other features, aspects and advantages of the present invention will become more apparent from the following description, appended claims and drawings.

## BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a flow sheet illustrating the charging and withdrawal system and process of the present invention; and

FIG. **2** is a view of the preferred sequential fill limiter and discharge valve assembly of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The system of the present invention will be described initially with reference to FIG. **1.** In this Figure, a natural gas compressor **10** is illustrated. This compressor may be of any well known forms and obviously compresses gas from a source at relatively low pressure to some predetermined pressure for discharge into a line **12.** A bank of containers or bottles consisting of containers **14, 16** and **18** are in communication with line **12** through respective sequential fill and discharge valves **20, 22** and **24.** The containers are connected in series through their respective sequential fill and discharge valves both for their charging and discharge. Each container can, of course, be replaced by two or more containers.

In the embodiment illustrated and for reasons to become apparent subsequently, when there is not enough time to bring all the containers up to rated pressure between withdrawals, container **14** will always have a residual pressure before charging in excess of the residual pressure in containers **16** and **18.** Similarly, container **16** will have a residual pressure before charging in excess of the pressure existing in container **18.** Of course, if there is sufficient charging time between withdrawals, all the containers will be at the same pressure. But for purposes of this discussion it will be assumed that there is insufficient time to bring all the containers up to their rated pressure before withdrawal to a vehicle's gas storage tanks.

Sequential fill and discharge valve **20** for container **14** controls the flow of gas to downstream containers **16** and **18** such that when container **14** is being charged no gas passes past valve **20** to the downstream containers.

Conversely, during withdrawl of gas from the containers, sequential fill and discharge valve **24** prevents discharge of gas from containers **14** and **16** until the gas in container **18** is effectively exhausted. The same is true of sequential fill and discharge valve **22** which prevents the withdrawal of gas from container **14** until container **16** is effectively exhausted.

To accomplish these ends, each of the valves **20, 22** and **24** has a fill side and a withdrawal side, indicated in FIG. **1** for the fill side by reference numerals **20***a*, **22***a* and **24***a*, and for the withdrawal side by reference numerals **20***b*, **22***b* and **24***b*.

The fill side of valves **20** and **22** are in series gas communication through a line **26.** As will become apparent subsequently, line **12** from the compressor leads directly to the withdrawal side of valve **20** so that when valve **20** is in its draw position gas from the compressor will pass through the valve and through a line **27** to the inlet side of the valve. The fill side of valves **22** and **24** are in series gas communication through a line **28.**

The withdrawal sides of valves **20** and **22** are in series gas communication through a line **30,** and the withdrawal sides of valves **22** and **24** are in series gas communication through a line **32.** The withdrawal side of valve **24** leads to the vehicle tanks to be charged through a line **34.**

The system illustrated in FIG. **1** has a transfer valve **36** in line **34** emanating from the withdrawal side of valve **24** for the initiation of gas withdrawal from the containers.

The fill side of each valve has a fill position and a transfer and off position. Each valve has a valving element, such as a spool, which is positionally responsive to a reference pressure and the particular valve's container pressure, such that when the reference pressure exceeds the container pressure the valve is in its fill position and gas can enter the container. When the container pressure exceeds the reference pressure, the particular valve will go to its transfer and off position. In the transfer position a valve admits to gas flow downstream from it and stops gas flow to its associated container. When valve **24** is in its transfer position, gas is recycled through a line **37** back to the compressor inlet, or to a pressure switch which stops the compressor, at the option of the user. In FIG. **1,** the reference pressure is supplied by reference pressure vessels **38, 40** and **42** through lines **44, 46** and **48** for valves **20, 22** and **24,** respectively. Gas communication from and to valves **20, 22** and **24** to and from containers **14, 16** and **18** is through lines **50, 52** and **54,** respectively.

The withdrawal side of each valve has a container bypass position and container draw position. In the container draw position for a given valve, gas can be drawn from that valve's container. In the bypass position for a given valve, gas cannot be withdrawn from its container but only from a container upstream from it, or in the case of valve **20,** from compressor **10.** To effect this type of operation each valve has a second valving element, such as a spool, which is positionally responsive from its draw position to its bypass position when container pressure drops below a given valve relative to the pressure in the tanks being charged. Conversely, each valve shifts from its bypass position to its draw position when its container pressure exceeds a given value relative to the pressure in the tanks being charged. The withdrawal side of each of the valves **20, 22** and **24** is in pressure communication with the tanks being charged through parallel branch lines **56, 58** and **60,** respectively, all of which are connected to the tanks

being charged downstream of transfer valve **36** through a common line **62.**

With reference to FIG. **2,** a more detailed depiction of sequential fill and discharge valve **22** is presented. This valve is identical in construction to valves **20** and **24** and is connected into the system illustrated in FIG. **1** identically, save for minor details to be described subsequently.

In general, valve **22** has a housing **64** having aligned bores **66** and **68** which receive fill limiter and transfer spool **70** and a draw and bypass spool **72.** Spool **70** is in fill side **22***a* and spool **72** is in transfer side **22***b*. The fill side of the valve will be initially described.

Line **26** from valve **20** opens into bore **66** for incoming gas and, as such, constitutes an inlet line for the valve. Line **28** also opens into the bore for outgoing gas to valve **24** and, as such, constitutes an outlet line from the valve. A chamber **74** midway between the fill and transfer side of the valve is in communication with container **16** through line **52.** A reference pressure chamber **76** is in pressure communication with reference pressure vessel **40** through line **46.**

Spool **70** is generally cylindrical and has an annular, relatively elongated flow channel **78** bounded by lands **80** and **82** for communicating inlet line **26** with outlet line **28** when the pressure in chamber **74** is sufficient to overcome the pressure in reference chamber **76.** An axial passage **84** in spool **70** opens into chamber **74** and is in communication with an annular channel **86** through one or more radial passages **88.** Channel **86** is in communication with inlet line **26** in the fill position of the valve, which is the position illustrated in FIG. **2.**

Means are provided to prevent axial gas flow between the lands of the spool and the wall of the bore such as a pair of O-rings **90** on either axial side of channel **78** and a pair of O-rings **92** on either axial side of channel **86.**

The reference pressure chamber, as previously mentioned, is in direct communication with reference pressure vessel **40.** The latter vessel is in thermal communication with container **16.** As such, the pressure in the reference pressure chamber is determined by the temperature of gas within container **16.** Because the gas in the reference pressure chamber line **46** and vessel **40** constitutes a closed system, the reference pressure in the chamber is a direct function of temperature. As a consequence, when the temperature in container **16** is relatively high, so will be the pressure in reference pressure chamber **76.** The converse is also true.

The pressure in vessel **40,** acting in chamber **76,** is such that during charging spool **70** will shift to its transfer position when the pressure exerted on it from container **16,** acting in chamber **74,** reaches a predetermined value of, say, 2,265 p.s.i. at 70° F.

On the withdrawal side of the valve, spool **72** is capable of translation in bore **68** between a draw position and a bypass position. The position illustrated in FIG. **2** is the draw position. Line **32** opens into a transfer chamber **94** and is in direct communication through this chamber with chamber **74** and container **16** when spool **72** is in its draw position. Line **30** opens into bore **68** and emanates from the transfer chamber of valve **20.**

One end of spool **72** sees the pressure in the tanks being charged through line **58** which opens into a reference pressure chamber **96.** In addition, a biasing spring **98** is disposed to act between an end of housing **64** and spool **72** and exerts predetermined biasing pressure on the spool of, say, 50 p.s.i., which tends to move the spool to its bypass position.

Spool **72** has an annular bypass channel **100** disposed to bridge the distance between line **30** and a line **101** in the draw position and between lines **30** and **32** to communicate the two in the spool's bypass position. Line **101** is blocked in each valve except in valve **20** where it is shown by reference numeral **27.** Line **27** leads to the part of valve **20** corresponding to line **26** in FIG. **2.** Again, O-rings are provided to prevent leakage of gas from or to the channel along the interface between the spool and the wall of bore **68.** These O-rings are indicated by reference numerals **102, 104** and **106** and are disposed in lands **108, 110** and **112,** respectively.

Spool **72** shifts to its bypass position when the pressure in the tanks being charged and biasing spring **98** is sufficient to overcome the pressure within container **16** acting in chamber **74.**

The differences in the system connections for the valves **20** and **24** over those for valve **22** will now be described.

For valve **24,** line **34** leads from the valve at the same location that line **32** leaves valve **22** but goes directly to the tanks being charged. Line **37** leads either to a compressor shutdown device or the compressor inlet when all tanks are filled. In other words, envisioning valve **22** as valve **20** during withdrawal, the compressor will be in direct communication with line **26** through line **30,** channel **100** and line **101.** With this communication, the compressor directly charges the vehicle's tanks. When the pressure in container **14** approaches vehicle tank pressure, the spool of valve **20** corresponding to spool **72** will move to the bypass position, dropping container **14** out of fluid circuit. However, compressor **10** will still be in communication with the vehicle's tanks through channel **100** and line **26** (the latter corresponding to line **32** in FIG. **2**).

For valve **20,** the compressor is connected through line **12** to the part corresponding to line **30** in FIG. **2** so that when all available gas has been transferred from container **14** to the vehicle being charged, the movement of the spool of valve **20** corresponding to spool **72** will connect the compressor directly to the vehicle. During this final filling mode no gas will be placed in the storage tanks.

The filling sequence of containers **14, 16** and **18** will now be described. Typically, the pressure in the containers will progressively decrease from container **14** to container **18** before the beginning of filling and each container will be below its filled pressure. In this condition, the fill limiter and transfer spool of valve **20** corresponding to spool **70** of valve **22** will be in its fill position. Since no vehicle is connected at the outlet of valve **24,** all withdrawal valves will be in the draw position. The compressor is then connected through lines **12** and **27** to container **14.** Communication with containers downstream of valve **20** is not possible because the fill limiter and transfer spool of valve **20** prevents communication with downstream valves by blocking line **26.** When the pressure in container **14** is sufficient to overcome the pressure in the reference chamber of the valve, the spool will be forced to its transfer position, and lines **12** and **26** will be in communication with one another. At this time, container **16** will begin to be fil-

led and container **14** will be out of communication with the compressor **10.** The same sequence of events will progressively occur for containers **16** and **18.**

So long as container **18** has more pressure than the vehicle to be charged, withdrawal will begin with container **18.** The draw and bypass spool of valve **24** for this container will be in its draw position. In the draw position, container **18** will communicate with the tanks in the vehicle through the transfer chamber of that particular valve and line **34.** When the pressure in the tanks of the vehicle and the pressure in container **18** approach one another, the biasing spring of valve **24** and tank pressure will force the draw and bypass spool to its bypass position and gas transfer to the tanks of the vehicle will switch to container **16.** The same sequence of events occurs in changing from container **16** to container **14.**

In the event that container **18** should have less pressure than the vehicle to be charged at the beginning of withdrawal, container **16** will transfer its gas first, followed by container **14.** As previously mentioned, valve **20** admits to direct communication between the tanks of the vehicle being charged and the compressor.

The present invention provides a charging system and process which, by charging storage containers having the highest beginning residual pressure first, maximizes the filling of vehicle tanks because the charging sequence maximizes available container pressure. The system and process of the present invention also maximizes vehicle tank filling by drawing from the container having the lowest beginning pressure, then progressively shifting to containers having gas under higher pressure. This again assures the effective maximum utilization of the filling force afforded by container pressure. Thus, for a given capacity charging system the fill time for vehicles using compressed gas is maximized.

The present invention has been specifically described with reference to its presently preferred embodiment. The spirit and scope of the appended claims should not, however, necessarily be limited to the foregoing description. For example, while the invention has been described with reference to the charging of the fuel tanks of vehicles using natural gas, the invention has utility in other environments.

What is claimed is:

**1.** A process for charging a plurality of containers with a gas in an order to produce the maximum available driving pressure in them in a given amount of charging time comprising:

charging the container having the highest initial pressure with the gas to a predetermined pressure and then charging as many of the remaining containers in the order of their highest initial pressure with the gas to the predetermined pressure as is possible in the charging time.

**2.** A process for charging a plurality of containers with a gas in an order to produce the maximum available driving pressure in them in a given amount of charging time and then for withdrawing gas from the charged containers in an order to produce the maximum fill in tanks being charged by the container comprising:

charging the container having the highest initial pressure with the gas to a predetermined pressure and then charging as many of the remaining containers successively and individually in the order of thier highest initial pressure with the gas to the predetermined pressure as is possible in the charging time, and then

charging the tanks with gas from the containers by withdrawing gas from the container having the lowest initial pressure first and then withdrawing gas successively and individually from the remaining containers in the order of their lowest initial pressure until the tanks have been charged.

* * * * *

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,807,422 Dated April 30, 1974

Inventor(s) Robert W. McJones

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the specification: Column 4, line 60, "valve" should be --value--.

In the claims: Claim 2, column 8, line 28, "thier" should be --their--.

Signed and sealed this 12th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents