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(54) **HIGH-ENERGY EFFICIENCY PLANT FOR AUTOMOTIVE METHANE COMPRESSION**

ANLAGE MIT HOHER ENERGIEAUSBEUTE FÜR KRAFTFAHRZEUGMETHANVERDICHTUNG

INSTALLATION À HAUT RENDEMENT ÉNERGÉTIQUE POUR LA COMPRESSION DE MÉTHANE POUR AUTOMOBILE

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DescriptionTechnical Field

[0001] The present invention relates to the process of compression of natural gas for automotive use and more particularly to a high-energy efficiency automotive methane compression plant.

Background Art

[0002] The current technique in the sector of automotive methane compression plants envisages a pressure increase from the pressure found in the pipeline (which ranges from 4 bar to approx 40 bar) to 280 bar, required for filling operations, using a multistage compressor with intercooler.

[0003] The system entails the construction of a compressor with suitable capacity for the (requirements of the plant, related to the dispensing capacity commonly required once in operation. A cooling phase is needed between stages to lower the initial temperature of the compressed gas in each stage, thus reducing energy consumption, and to protect the compressor's seal parts.

[0004] These systems therefore require single-acting or double-acting multi-cylinder compressors designed so that the respective volumes are appropriate for the density variations in a capacity that must be identical in each individual stage.

[0005] Prior art already knows such multi-cylinder compressors, disclosed for example by document FR 2503279, which is considered as the closest prior art, wherein a compressor group is shown which is provided with a plurality of compression stages compressors mounted on a single shaft. The compressors are provided with closable bypass lines in order to achieve low an idling power as possible as quickly as possible when starting-up or when changing to idling mode.

[0006] Another example of such compressors is found in the document EP 0757179 wherein it is shown a compressor apparatus for refrigerant circuits, which is provided with a turbocompressor with a plurality of compression stages mounted on a single shaft. The apparatus comprises mixer devices, interposed between two successive compressor stages, into which the main gas and infeed flows are introduced. The two flows are mixed in the mixer device in such a manner that the flow leaves the mixer device with a homogeneous temperature distribution and velocity distribution before working into the next stage of said turbocompressor having a plurality of compression stage In the prior art, and more particularly in the sector of automotive methane compression plants, cooling requires large and consequently expensive systems, which considerably influence final plant cost. In fact they need to cool the gas predominantly with air or with water circuits. In addition, the compressor is subject to continuous starts and stops in relation to the gas withdrawn with each customer use. This is one of the principal

factors affecting reliability, and requires appropriate over-dimensioning in the design stage.

stage.

[0007] The operating problems of these plants increase at high ambient temperatures (e.g. tropical countries) by affecting the intercooler system.

[0008] A traditional plant of the type described above is schematically illustrated in Figure 1.

Disclosure of the Invention

[0009] A primary object of the present invention is to overcome the drawbacks of known plants by providing a plant operating with significantly higher energy efficiency.

[0010] A second object of the invention is to provide plants capable of achieving the pressure changes enabled by known plants, using a much simpler and consequently less expensive design and one that is more reliable compared with similar known designs. An additional object of the invention is plants with a smaller compressor.

[0011] A further object is to provide plants with compressors designed for continuous operation, more reliable than traditional compressors operating intermittently.

[0012] In line with the invention such objects are met by a plant that - under claim 1 and/or any of the directly or indirectly dependent claims- uses a one-stage compressor and suitable intermediate storing systems at different pressures, placed in a cooled environment. From the pipeline pressure the gas is brought to low pressure via a single compression stage, it is stored, brought to medium pressure and finally to the final pressure.

[0013] The pressure changes are achieved by the same compressor through a switch of delivery with suction. The compressor achieves the different pressures via different delivery periods according to the amount of gas stored in the cylinders.

[0014] At the filling station, the customer's vehicle will be supplied first with low-pressure methane, then with medium-pressure and finally with maximum-pressure gas. This will provide for the total mass of gas required to achieve maximum pressure to be delivered into the vehicle's tanks or cylinders, thus saving the energy that would be needed to bring the whole mass to maximum pressure.

Brief description of the drawings

[0015] The advantages of a plant constructed according to the disclosed invention are illustrated below in the detailed description of a preferred embodiment that is merely illustrative but does not delimit the plant, where :

- figure 1 is a basic drawing of a conventional compression plant;
- figure 2 is a functional diagram of the plant fed at ca.

- 20 bar showing the different pressure levels;
- figure 3a is a functional diagram of the stage where the low-pressure cylinder is fed by gas from the pipeline;
- figure 3b is a functional diagram of the stage where the medium-pressure cylinder is fed by gas from the low-pressure cylinder;
- figure 3c is a functional diagram of the stage where the high-pressure cylinder is fed by gas from the medium-pressure cylinder;
- figure 4 is a functional diagram of the customer dispensing stage, with multiple, successive fillings from the three different cylinders;
- figure 5 is a basic drawing of a plant constructed according to the disclosed invention, endowed with a stage of adjustment to pipeline suction pressure.

Detailed Description of the Preferred Embodiments of the Invention

[0016] In the figures of the attached drawings, 1 indicates a gas compression plant of the type endowed with a gas compressor 2 and a cylinder casing 3.

[0017] The compressor 2 is a one-stage apparatus that is fed natural gas from the pipeline through a suction conduit 9 which channels the compressed gas to a feed conduit 10. The pipeline gas enters the suction conduit 9 of the compressor 2 at an initial pressure of ca. 20 bar and exits the feed conduit 10 at a maximum pressure of ca. 290 bar. The pressure change from initial to final pressure is achieved by the compressor 2 in three successive compression stages, among which the total pressure difference is appropriately divided.

[0018] The cylinder casing 3 is comprised of as many cylinders 4 as the compression steps or stages, each cylinder 4 storing compressed gas substantially at the maximum pressure achieved in each of the stages into which the total pressure difference has been subdivided.

[0019] The plant 1 also includes means to feed the compressor 2, before the execution of each of said consecutive stages, with gas from the cylinder 4 that has been filled last. This is shown in greater detail in figures 3a, 3b and 3c, where the functional diagrams of the three phases of compression and storage are illustrated.

[0020] As shown in figure 3a, the gas from the feed line 14 is compressed from the initial pipeline pressure [ca. 20 bar] to a low pressure LP of ca. 49 bar.

[0021] This is achieved by sucking natural gas from the feed line 14, while an inlet valve 11 placed on said line, a valve 12 placed upstream of a first low-pressure LP cylinder 4, and a valve 13 placed on a first branching 15 connecting the feed conduit 10 to the first low-pressure LP cylinder 4 are all open.

[0022] As illustrated in figure 3b, the gas is compressed to the medium pressure MP of ca. 120 bar. Compression of the natural gas in the compressor 2 is achieved by sucking gas from the low-pressure LP cylinder 4, keeping open valve 12 and a valve 17 placed on

a tract 20 of the conduit that connects the LP cylinder 4 to the suction conduit 9 of the compressor 2. An inlet valve 18 to the medium-pressure MP cylinder 4, and a valve 19 placed on a second branching 21, connecting the feed conduit 10 to the medium-pressure MP cylinder 4, are also open.

[0023] As shown in figure 3c the gas is compressed to the maximum pressure [ca. 290 bar]. The compression is achieved by sucking gas from the medium-pressure MP cylinder 4, with valves 17 and 18 open. A valve 22 placed on a tract 23 of the conduit that connects the medium-pressure MP cylinder 4 to the suction conduit 9 of the compressor 2 via tract 20 and an inlet valve 24 to the high-pressure HP cylinder 4 positioned on a third branching 25 of the feed conduit 10 are also open.

[0024] The filling of a vehicle's storage cylinder is represented in figure 4. Operations begin with filling the vehicle's storage cylinder with gas at a pressure slightly greater than the pressure found inside it, by keeping open an interception valve 26 of a dispensing hose 28 and an outlet valve 27 of the low-pressure LP cylinder 4.

[0025] Once the low pressure has been achieved, the cylinder of the vehicle is filled from the medium-pressure MP cylinder 4, with valve 26 and an outlet valve 29 of the medium-pressure MP cylinder 4 being open.

[0026] Once this step has been completed the cylinder of the vehicle is finally filled with gas from the high-pressure HP cylinder 4, with valve 26 and an outlet valve 30 of the high-pressure HP cylinder 4 open.

[0027] In the description of the operation of the plant 1, storage and delivery of natural gas are described as being independent of one another. Clearly, storage and delivery can be performed simultaneously.

[0028] The plant 1 comprises cooling means 5 of the gas stored in the cylinders 4. The system can be embodied in a conventional cooling system with a compressor 31, whose function can be performed by the same compressor 2 compressing the natural gas.

[0029] The cooling system can be provided with motors to power the compressor 31. These can be either separate or be the same as the motor 6 powering the natural gas compressor 2.

[0030] The motors can be indifferently electrical or thermal.

[0031] Alternatively, cooling can be provided by a high-thermal capacity fluid spraying system associated with the cylinders 4 in the cylinder casing 3.

[0032] In particular the cylinders, stacked on racks, can be sprinkled from above with a refrigerated water and ethyl alcohol solution by a system of nozzles; the solution, collected in a tub, can then be sucked by a pump that returns it to the cooling system to be cooled again. The system requires a casing for the racks and the tub.

[0033] An alternative embodiment is one where cooling is provided by a tub containing a high-thermal capacity fluid in which the cylinders 4 are immersed.

[0034] More in particular the cylinders 4, however packaged, shall be placed into large, water-tight steel

vessels filled with a water and ethyl alcohol solution from the cooling system: as in the case mentioned above, the fluid is returned to the fridge to be cooled again. Where available, filtered well water circulated periodically can be used as an alternative to the cooling system.

[0035] In either case, it is the cylinders that work as heat exchangers. Therefore devices that increase the heat exchange, e.g. fins, can be added if needed.

[0036] According to the disclosed invention, the plant 1 is fitted with sensor means 8, operatively associated with compressor 2 and with the cylinders 4. Upon detecting the achievement of the maximum pressure in each cylinder 4, said sensor means 8 switch off gas inlet into the compressor 2, by activating its connection to the downstream cylinder 4 and switch on the suction of the compressor 2 by activating its connection to the upstream cylinder 4 filled in the previous compression stage.

[0037] The pressure of the individual stages is defined by customer habits. The minimum pressure in the storage cylinder of a vehicle at a filling station is about 30 bar. This dictates the low-pressure value, which will reasonably exceed 30 bar; a value of about 50 bar is considered suitable.

[0038] Since the maximum allowed filling pressure is usually around 300 bar, the medium pressure is approx. 120 bar.

[0039] Since a single compressor is used, a proper 49-120-294 progression is achieved by a constant compression ratio, equal to 2.45, starting from a pipeline pressure of 20 bar. For higher pipeline pressures a suitable compression ratio is calculated and the pressure progression is adjusted. For lower pipeline pressures, a pressure adjustment stage shall be required to reach 20 bar, with a storage and a cooling stage.

[0040] A basic drawing of such a plant is reported in figure 5; it envisages a pipeline pressure of 4 bar, common in Italy and requires an additional compressor with a compression ratio of 5.

[0041] The disclosed design fully meets the above requirements and also achieves additional advantages.

[0042] One additional advantage is that a single compressor 2 and a single compression stage subserve the storage of gas at intermediate pressures by acting only on the pressure difference between stages and only on a limited amount of gas, i.e. the amount of gas delivered to the cylinder casing 3.

[0043] This results in considerable energy savings.

[0044] In addition, the overall lower compression ratio required of the compressor 2 enables use of small compressors 2, with lower plant and operating costs.

[0045] The continuous operation design of the compressor 2 entails the additional advantage of greater plant 1 reliability.

[0046] A further advantage is that the cylinders 4 can also serve as coolers.

[0047] Several changes and modifications of the invention can be implemented by experts in the field, who will choose the most appropriate dimension and con-

struction materials according to the type of application. Such changes are thus to be viewed as inherent to the invention and as encompassing the object of the claims below.

Claims

1. A gas compression plant of the type comprising at least one gas compressor (2) and at least a cylinder casing (3), **characterized in that** said compressor (2) is a one stage compressor which achieves complete compression of the gas through at least two consecutive compression steps, said consecutive compression steps are achieved by means of successive compression steps through said one stage compressor (2), said cylinder casing (3) comprising as many cylinders (4) as there are compression steps, said cylinders (4) storing gas compressed substantially to the maximum pressure achieved in each of said steps, and feed delivery means (7) to dispense compressed gas to fill vehicle's storage cylinder; said plant being provided with means to feed said compressor (2), prior to the execution of each successive steps, with gas from the previous compression step, stored in the respective cylinder (4).
2. A plant, according to claim 1, **characterized in that** it comprises cooling means (5) of the gas stored in said cylinders (4).
3. A plant, according to claim 2, **characterized in that** said cooling means (5) comprise a cooling system.
4. A plant, according to claim 2, **characterized in that** said cooling means (5) comprise a high-thermal capacity fluid spraying system associated with the cylinders (4) arranged in said cylinder casing (3).
5. A plant, according to claim 2, **characterized in that** said cooling means (5) comprise a tub containing a high-thermal capacity fluid in which said cylinders (4) are immersed.
6. A plant, according to claim 3, **characterized in that** said cooling system comprises a compressor (2), said gas compressor (2) being the compressor (2) powering the cooling system.
7. A plant, according to claim 3, **characterized in that** said cooling system comprises motors (6), said gas compressor (2) being powered by motors (6) that also power the cooling system.
8. A plant, according to claim 1, **characterized in that** said compressor (2) is powered by electrical motors (6).

9. A plant, according to claim 1, **characterized in that** said compressor (2) is powered by thermal motors (6).
10. A plant, according to claim 1, **characterized in that** said cylinders (4) simultaneously store and deliver compressed gas.
11. A plant, according to claim 1, **characterized in that** said complete compression is achieved through three consecutive compression steps.
12. A plant, according to claim 1, **characterized in that** it comprises sensor means (8) operatively associated with said compressor (2) and with said cylinders (4) which upon detecting the achievement of the maximum pressure in the different cylinders (4) switch off gas inlet into the compressor 2 by activating its connection to the downstream cylinder (4) and switch on the suction of the compressor (2) by activating its connection to the upstream cylinder (4) filled last.
13. A plant, according to claim 1, **characterized in that** said compressed gas is natural gas for automotive vehicles.

Patentansprüche

1. Eine Gaskompressionsanlage der Art, die mindestens einen Gaskompressor (2) und mindestens ein Zylindergehäuse (3) umfasst, **gekennzeichnet dadurch, dass** es sich bei besagtem Kompressor (2) um einen einstufigen Kompressor handelt, der die völlige Kompression des Gases mithilfe mindestens zweier aufeinander folgender Kompressionsschritte erreicht; besagte aufeinander folgenden Kompressionsschritte werden mithilfe aufeinander folgender Kompressionsschritte durch besagten einstufigen Kompressor (2) erreicht, wobei das besagte Zylindergehäuse (3) so viele Zylinder (4) enthält, wie es Kompressionsschritte gibt; besagte Zylinder (4) speichern Gas, das im Wesentlichen bis zum maximalen Druck komprimiert ist, der bei jedem der besagten Schritte erreicht wurde, und Versorgungsfördermittel (7), um komprimiertes Gas auszugeben, mit dem der Speicherzylinder des Fahrzeugs gefüllt wird; besagte Anlage ist mit Mitteln zur Versorgung des besagten Kompressors (2) vor der Durchführung der einzelnen, aufeinander folgenden Schritte ausgestattet; diese Versorgung geschieht mit Gas aus dem vorhergehenden Kompressionsschritt, das in dem Jeweiligen Zylinder (4) gespeichert ist.
2. Die Anlage nach dem Patentanspruch 1, **gekennzeichnet dadurch, dass** sie Mittel zur Kühlung (5)

des Gases, das in den besagten Zylindern (4) gespeichert ist, umfasst.

3. Die Anlage nach Patentanspruch 2, **gekennzeichnet dadurch, dass** besagte Kühlmittel (5) ein Kühlsystem umfassen.
4. Die Anlage nach Patentanspruch 2, **gekennzeichnet dadurch, dass** besagte Kühlmittel (5) ein Sprühsystem für eine Flüssigkeit mit hoher Wärmekapazität umfassen, das mit den Zylindern (4) verknüpft ist, die in besagtem Zylindergehäuse (3) angeordnet sind.
5. Die Anlage nach Patentanspruch 2, **gekennzeichnet dadurch, dass** besagte Kühlmittel (5) eine Wanne umfassen, die eine Flüssigkeit mit hoher Wärmekapazität enthält, in der besagte Zylinder (4) eingetaucht sind.
6. Die Anlage nach Patentanspruch 3, **gekennzeichnet dadurch, dass** besagtes Kühlsystem einen Kompressor (2) umfasst und der besagte Gaskompressor (2) der Kompressor (2) ist, der das Kühlsystem betreibt.
7. Die Anlage nach Patentanspruch 3, **gekennzeichnet dadurch, dass** besagtes Kühlsystem einen Motor (6) umfasst und der besagte Gaskompressor (2) durch den Motor (6) angetrieben wird, welcher auch das Kühlsystem betreibt.
8. Die Anlage nach Patentanspruch 1, **gekennzeichnet dadurch, dass** der besagte Kompressor (2) durch Elektromotoren (6) angetrieben wird.
9. Die Anlage nach Patentanspruch 1, **gekennzeichnet dadurch, dass** der besagte Kompressor (2) durch einen Thermomotor (6) angetrieben wird.
10. Die Anlage nach Patentanspruch 1, **gekennzeichnet dadurch, dass** besagte Zylinder (4) komprimiertes Gas gleichzeitig speichern und liefern,
11. Die Anlage nach Patentanspruch 1, **gekennzeichnet dadurch, dass** besagte vollständige Kompression durch drei aufeinander folgende Kompressionsschritte erreicht wird.
12. Die Anlage nach Patentanspruch 1, **gekennzeichnet dadurch, dass** sie Sensormittel (8) umfasst, die operativ mit besagtem Kompressor (2) und mit besagten Zylindern (4) verbunden sind und die bei Erfassung des Erreichens des maximalen Drucks in den verschiedenen Zylindern (4) den Gaseinfluss in den Kompressor (2) abschalten, indem sie seine Verbindung mit dem nachgeschalteten Zylinder (4) aktivieren, und das Ansaugen des Kompressors (2)

aktivieren, indem sie seine Verbindung mit dem zuletzt gefüllten, vorgeschalteten Zylinder (4) aktivieren.

13. Die Anlage nach Patentanspruch 1, **gekennzeichnet dadurch, dass** es sich bei dem besagten komprimierten Gas um natürliches Gas für Kraftfahrzeuge handelt.

Revendications

1. Une station de compression de gaz du type comprenant au moins un compresseur de gaz (2) et au moins une enveloppe de cylindre (3), **caractérisée en ce que** ledit compresseur (2) est un compresseur à un étage qui procède à la compression complète du gaz en au moins deux étapes de compression consécutives, lesdites étapes de compression consécutives sont exécutées par le biais d'étapes de compression successives à travers ledit compresseur à un étage (2), ladite enveloppe de cylindre (3) comprenant autant de cylindres (4) qu'il y a d'étapes de compression, lesdits cylindres (4) stockant le gaz essentiellement comprimé à la pression maximum atteinte dans chacune desdites étapes, et des moyens de distribution d'alimentation (7) destinés à distribuer le gaz comprimé pour remplir le cylindre de stockage d'un véhicule ; ladite station étant équipée de moyens pour alimenter ledit compresseur (2), avant l'exécution de chacune des étapes successives, avec le gaz obtenu à l'issue de l'étape de compression précédente, stocké dans le cylindre (4) respectif.
2. La station selon la revendication 1, **caractérisée en ce qu'elle** comprend des moyens (5) de refroidissement du gaz stocké dans lesdits cylindres (4).
3. La station selon la revendication 2, **caractérisée en ce que** les moyens de refroidissement (5) comprennent un système de refroidissement.
4. La station selon la revendication 2, **caractérisée en ce que** lesdits moyens de refroidissement (5) comprennent un système de pulvérisation d'un fluide à haute capacité thermique associé aux cylindres (4) disposés dans ladite enveloppe de cylindre (3).
5. La station selon la revendication 2, **caractérisée en ce que** les moyens de refroidissement (5) comprennent une cuve contenant un fluide à haute capacité thermique dans laquelle lesdits cylindres (4) sont plongés.
6. La station selon la revendication 3, **caractérisée en ce que** ledit système de refroidissement comprend un compresseur (2), ledit compresseur de gaz (2)

étant le compresseur (2) actionnant le système de refroidissement.

7. La station selon la revendication 3, **caractérisée en ce que** ledit système de refroidissement comprend des moteurs (6), ledit compresseur de gaz (2) étant actionné par des moteurs (6) qui actionnent aussi le système de refroidissement.
8. La station selon la revendication 1, **caractérisée en ce que** ledit compresseur (2) est actionné par des moteurs (6) électriques.
9. La station selon la revendication 1, **caractérisée en ce que** ledit compresseur (2) est actionné par des moteurs (6) thermiques.
10. La station selon la revendication 1, **caractérisée en ce que** lesdits cylindres (4) stockent et distribuent simultanément le gaz comprimé.
11. La station selon la revendication 1, **caractérisée en ce que** ladite compression complète est obtenue par le biais de trois étapes de compression consécutives.
12. La station selon la revendication 1, **caractérisée en ce qu'elle** comprend des moyens capteurs (8) opérationnellement associés audit compresseur (2) et auxdits cylindres (4) qui, suite à la détection de l'obtention de la pression maximum dans les différents cylindres (4), désactivent l'arrivée de gaz dans le compresseur (2) en activant sa connexion avec le cylindre (4) situé en aval et activent l'aspiration du compresseur (2) en activant sa connexion avec le cylindre (4) situé en amont rempli en dernier.
13. La station selon la revendication 1, **caractérisée en ce que** ledit gaz comprimé est du gaz naturel pour véhicules automobiles.

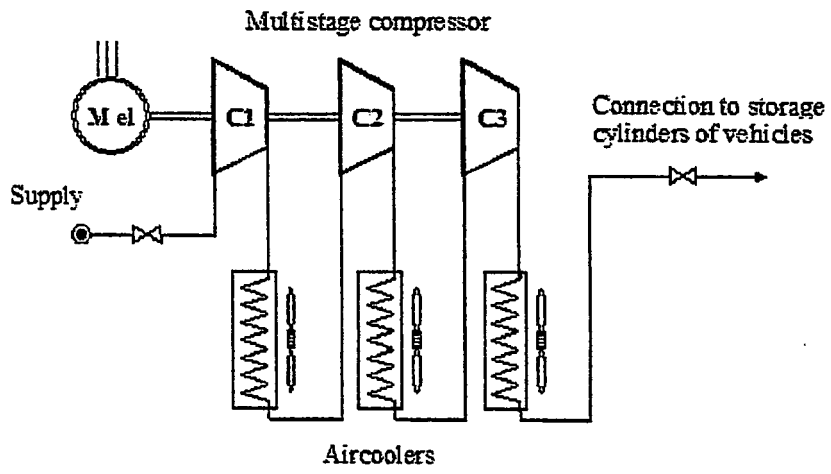


Figure 1

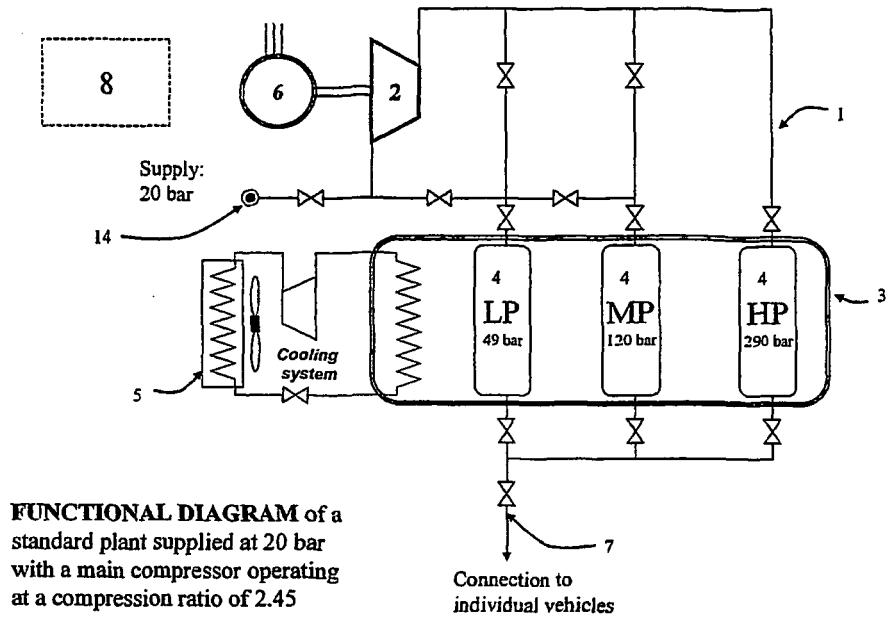


Figure 2

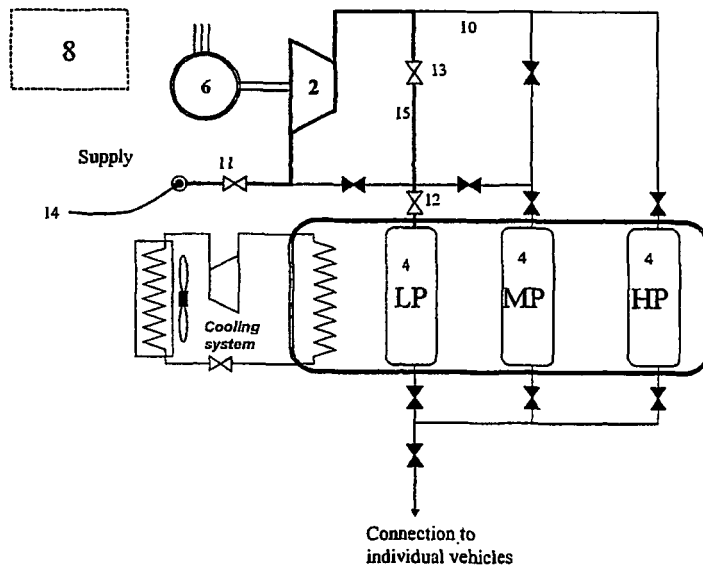


Figure 3 a

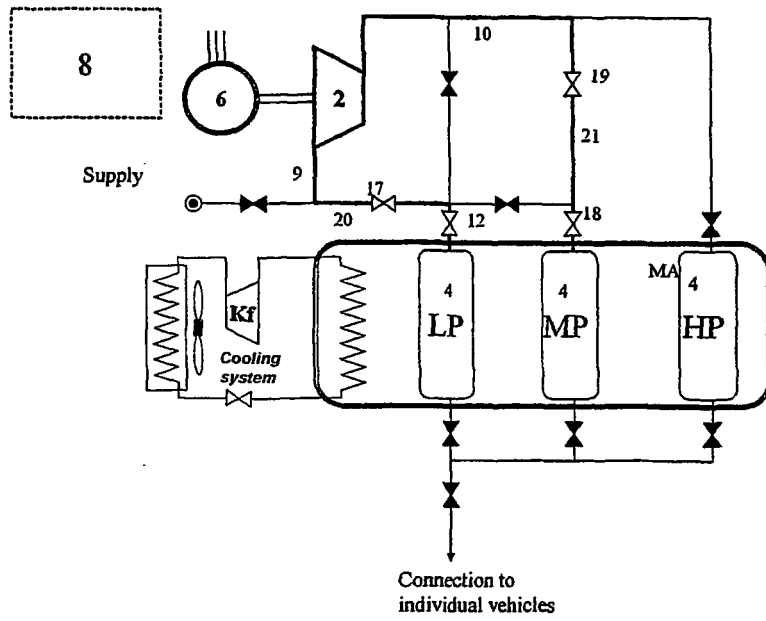


Figure 3b

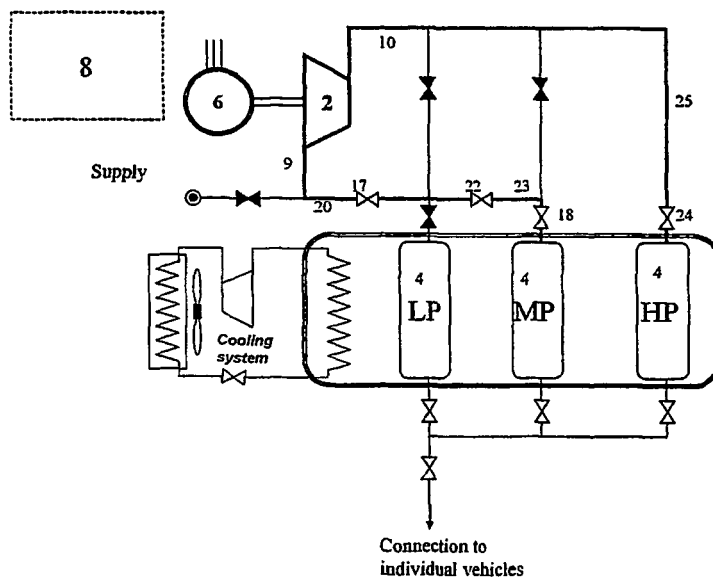


Figure 3c

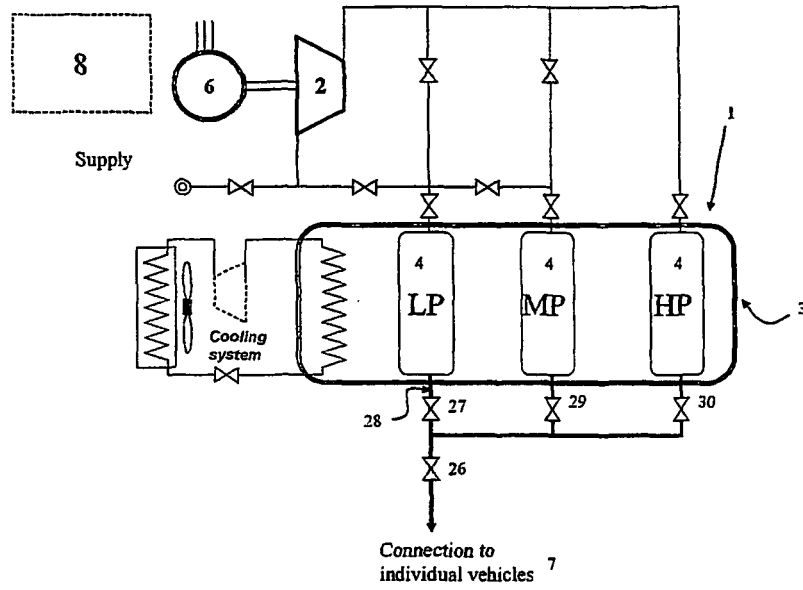


Figure 4

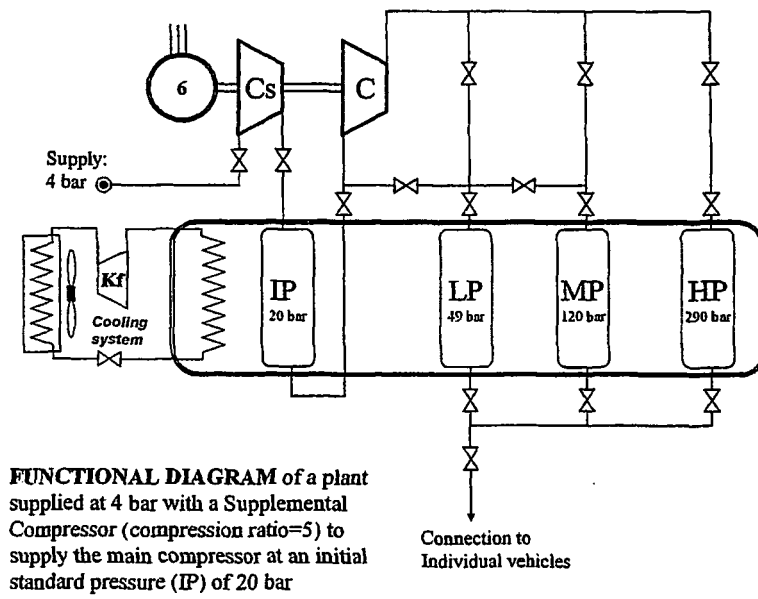


Figure 5

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Plant	1		
Gas compressor	2		
Cylinder casing	3		
Cylinder s	4		
Cooling means	5		
Motors	6		
Delivery means	7		
Sensors	8		
Suction conduit	9		
Feed conduit	10		
Valve AR	11		
Valve LA	12		
Valve LA1	13		
Feed line	14		
Low pressure LP (49 bar)			
First branching	15		
Valves LA2	17		
Valves MA	18		
Valve MA1	19		
Tract of conduit	20		
Second branching	21		
Valve	22		
Tract of conduit	23		
Valve	24		
Third branching	25		
Valve EU	26		
Valve LM	27		
Dispensing hose	28		
Valve MM	29		
Valve HM	30		
Compressor	31		

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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