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

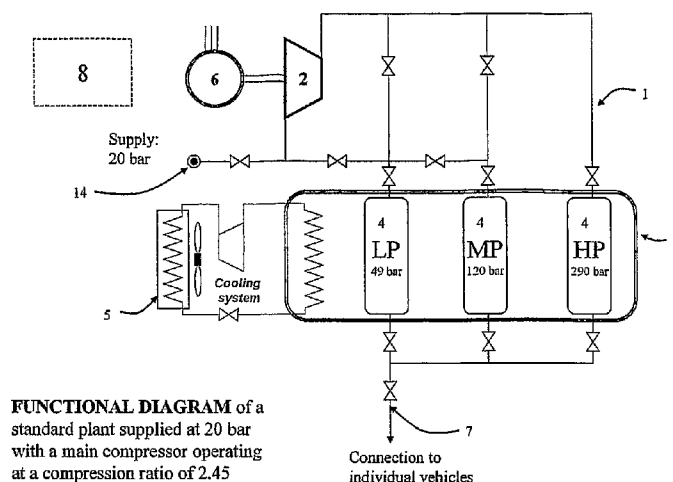


Figure 2

(57) Abstract: A gas compression plant (1) including at least a gas compressor (2) and at least a cylinder casing (3) is disclosed. The compressor (2) completely compresses the gas via at least two consecutive compression stages. The cylinder casing (3) contains as many cylinders (4) as the compression stages, the compressed gas being stored in the cylinders (4) substantially at the maximum pressure achieved in each compression stage. The gas compression plant (1) comprises means to feed the compressor (2), prior to the execution of each consecutive stage, with gas from the previous compression stage, stored in the respective cylinder (4).



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Description

High-energy efficiency plant for automotive methane compression

5 Technical Field

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.

10 Background Art

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.

15 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.

20 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.

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
25 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 In addition, the compressor is subject to continuous starts and stops in relation to the gas withdrawn with each customer use.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 overdimensioning in the design

stage.

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

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

5

Disclosure of the Invention

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.

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
10 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.

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

15 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
20 final pressure.

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.

At the filling station, the customer's vehicle will be supplied first with low-pressure
25 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

The advantages of a plant constructed according to the disclosed invention are
5 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;
- 10 - 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
15 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.

20

Detailed Description of the Preferred Embodiments of the Invention

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.

The compressor 2 is a one-stage apparatus that is fed natural gas from the pipeline
25 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.

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.

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.

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.

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.

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.

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.

The filling of a vehicle's storage cylinder is represented in figure 4. Operations begin
5 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.

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-
10 pressure MP cylinder 4 being open.

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.

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

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
20 gas.

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.

The motors can be indifferently electrical or thermal.

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

In particular the cylinder s, 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.

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

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
10 used as an alternative to the cooling system.

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.

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
15 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.

The pressure of the individual stages is defined by customer habits. The minimum
20 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.

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

25 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.

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
5 compression ratio of 5.

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

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
10 pressure difference between stages and only on a limited amount of gas, i.e. the amount of gas delivered to the cylinder casing 3.

This results in considerable energy savings.

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

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

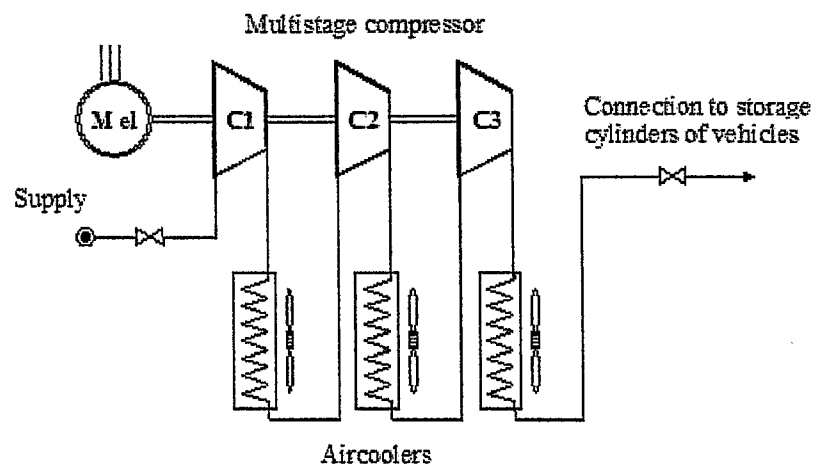
A further advantage is that the cylinders 4 can also serve as coolers.

Several changes and modifications of the invention can be implemented by experts in the field, who will choose the most appropriate dimension and construction materials
20 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) achieves complete compression of the gas through at least two consecutive compression stages,
5 said cylinder casing (3) comprising as many cylinders (4) as there are compression stages, said cylinders (4) storing gas compressed substantially to the maximum pressure achieved in each of said stages and being provided with means to feed said compressor (2), prior to the execution of each successive stage, with gas from the previous compression stage, stored in the respective cylinder (4).
- 10 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)
15 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.
- 20 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
25 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) feed delivery means (7) to dispense compressed gas to users.
- 5 11. A plant, according to claim 10, characterized in that said cylinders (4) simultaneously store and deliver compressed gas.
12. A plant, according to claim 1, characterized in that said complete compression is achieved through three consecutive compression stages.
13. A plant, according to claim 1, characterized in that it comprises sensor means
10 (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.
- 15 14. A plant, according to claim 1, characterized in that said compressed gas is natural gas for automotive vehicles.

**Figure 1**

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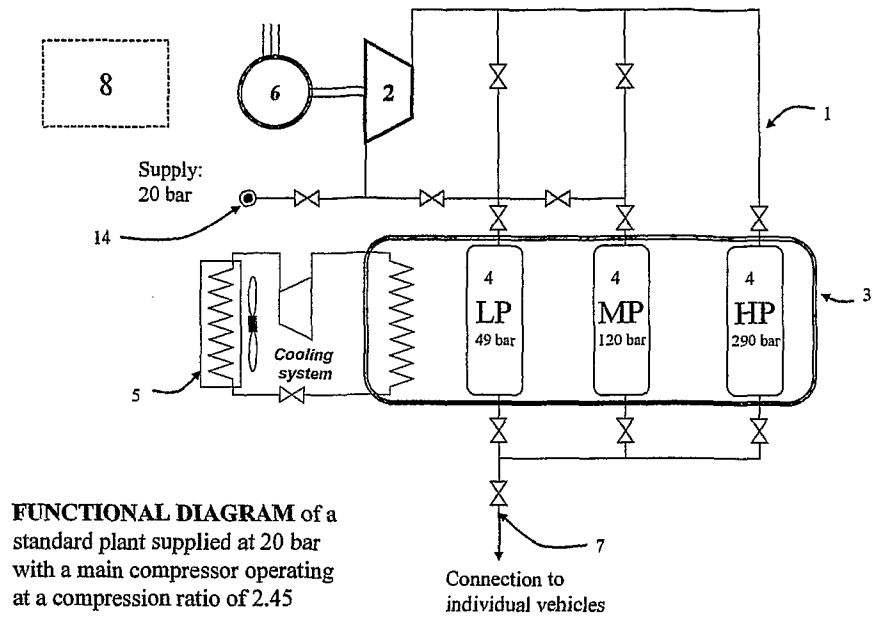


Figure 2

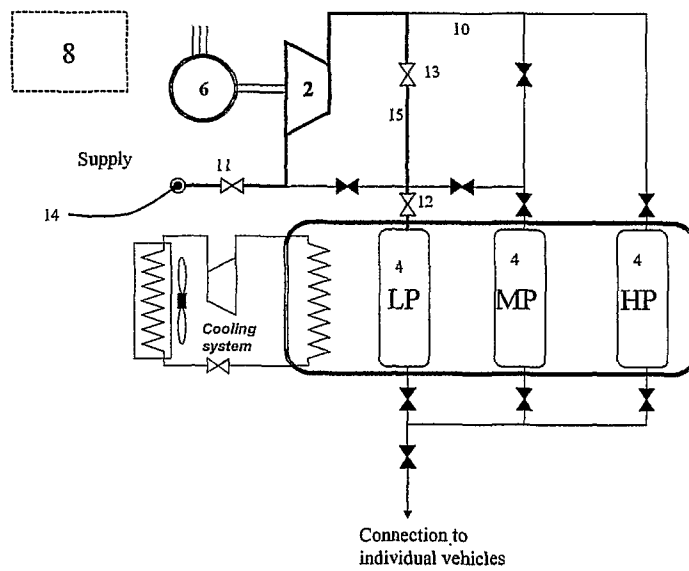


Figure 3 a

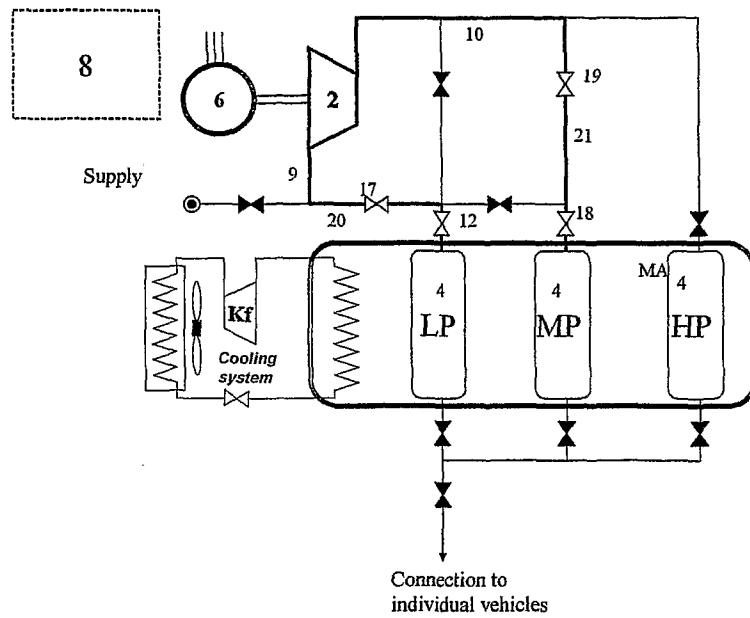


Figure 3b

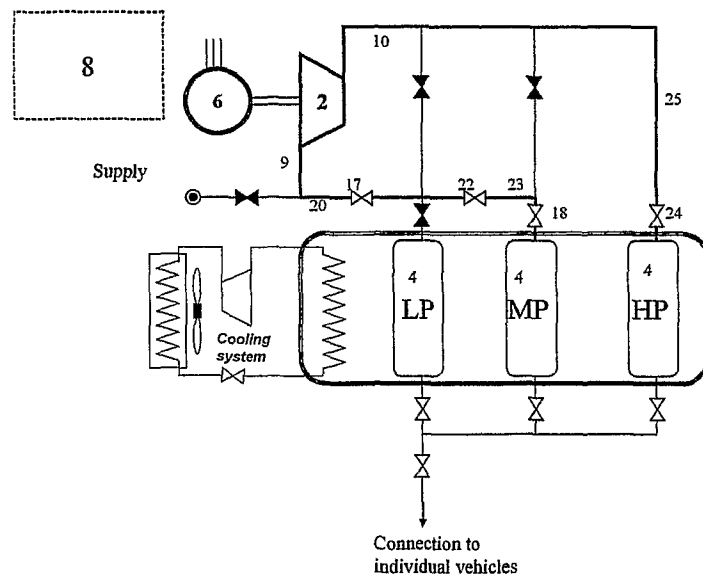


Figure 3c

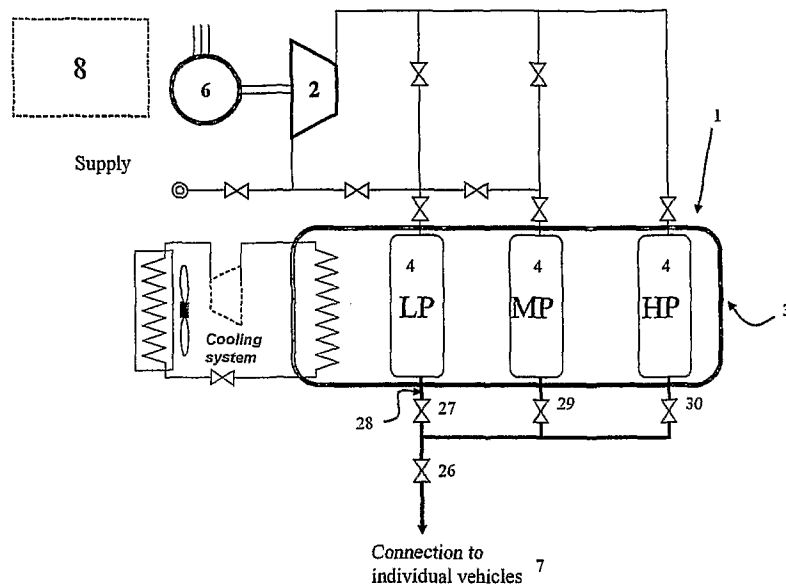


Figure 4

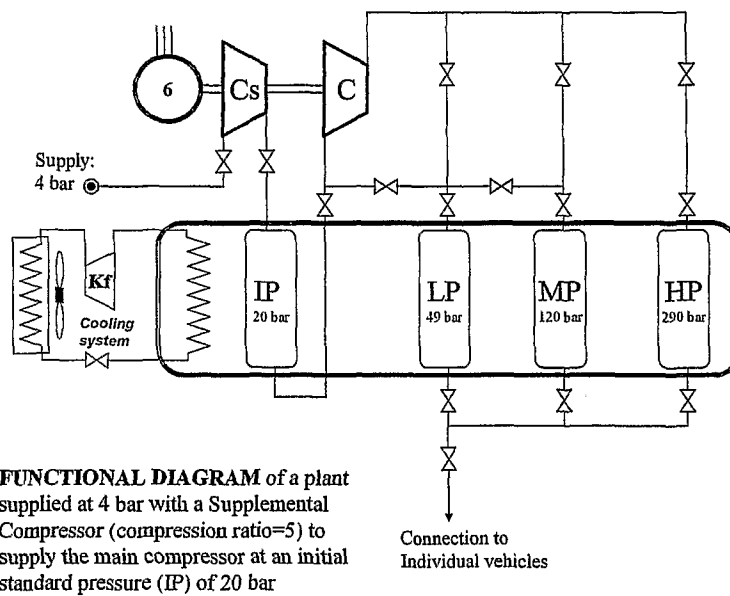


Figure 5

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		