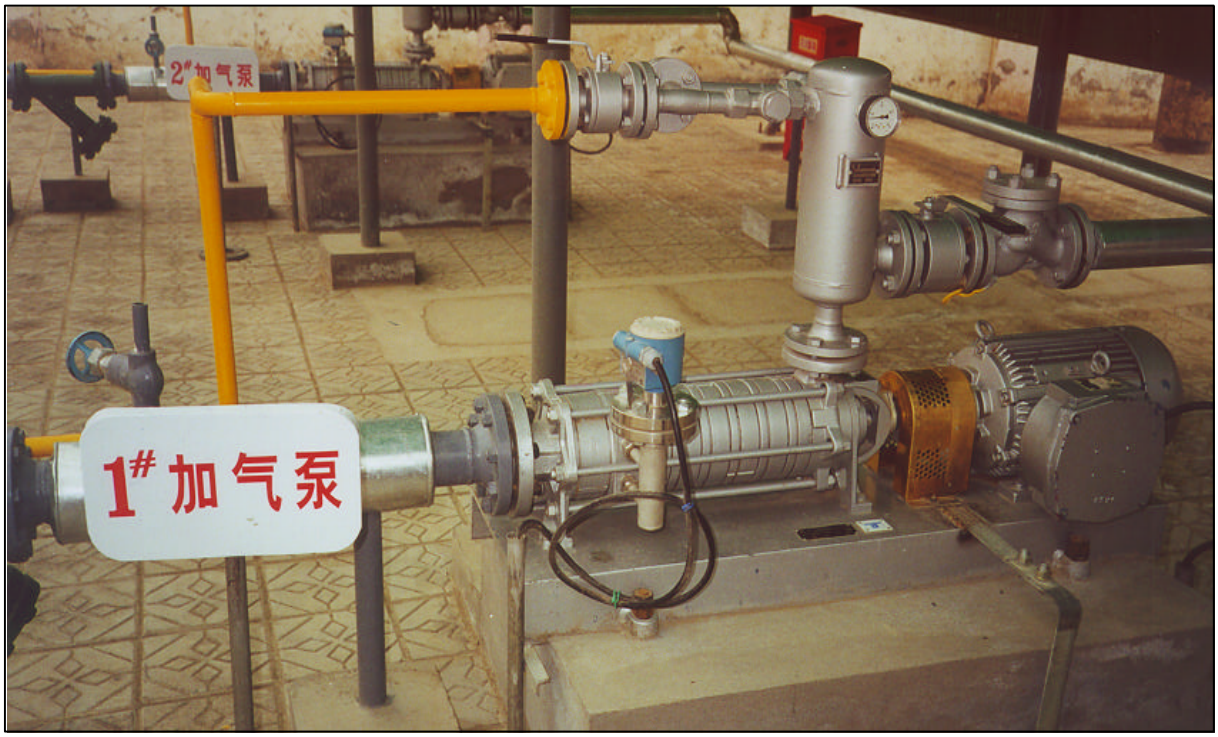
Autogas Application with Underground Tanks



1. Pumping System
2. Operating Principle
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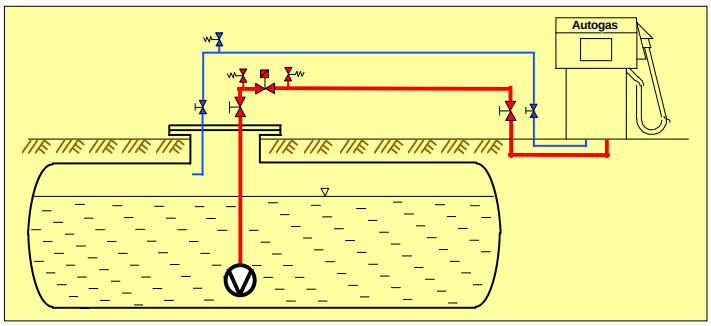
1. Pumping System

Technical safety regulations and the lack of space for safety distances require the installation of underground tanks where extraction of LPG is only possible by top-off loading via the dome flange.

Under normal conditions the pressure in the car tank will be higher than in the underground tank. Therefore a pressure generating pump is required to transfer the liquid from the underground tank to the car tank.

The pressure generating pump can be a vertical tank pump or a submersible pump which will be installed inside the pressurized tank.

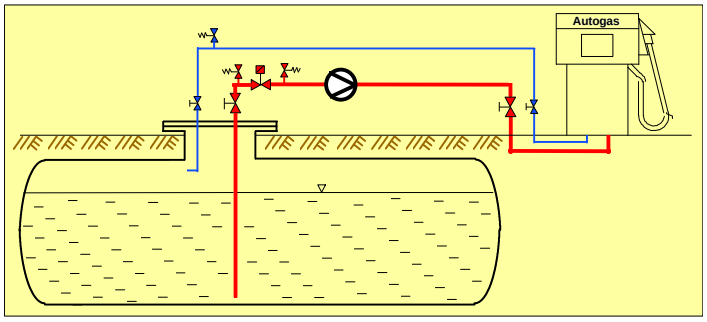


In the case of vertical submersible pumps the installation of an additional pump barrel is neces-sary to remove the pump for maintenance without draining the storage tank.

underground tank with submersible pump

When installing a barrel pump there is a minimum clearance distance between the bottom of the storage tank and the base of the barrel.

In order to satisfy the NPSH required by the submersible pump, the minimum liquid level in the storage tank is increased which means substantially less utilization of the tank capacity.



Alternatively the installa-tion can be with a top-mounted pump system outside the tank which operates on suction lift operation with only a suction pipe inside the tank.

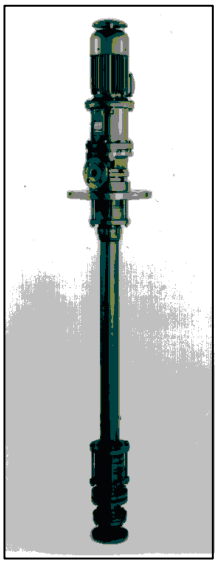
underground tank with top-mounted pump

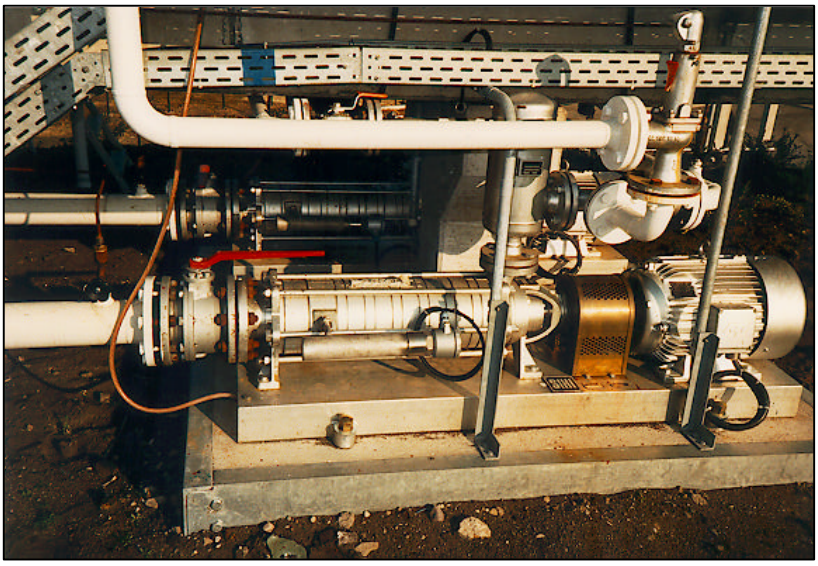
In this case no mechanical or electrical components are inside the pressurized tank (LPG storage) and there is easy access to the outside mounted pump for service and maintenance.

The minimum liquid level in the tank depends only on the safety distance between suction pipe and tank bottom which in this instance will only be a few centimetres. With this type of installation you obtain maximum utilization of the storage tank volume and considerably more than that with a submersible pump.

If both pumping systems are possible the question arises, which one is better or which system gives more benefits to the customer.

Technical as well as commercial aspects are of importance for the right decision.





submersible or top-mounted pump?

The following points should be evaluated before any decision is taken:

reliability
operating costs
revenue

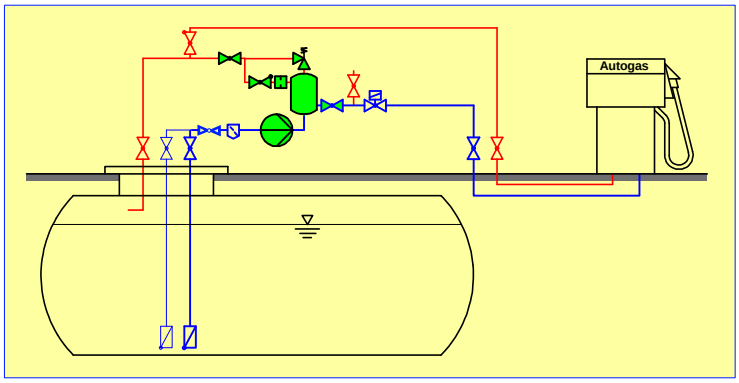
maintenance
economical options
initial costs

Subsequently the top mounted PC system offered the greatest benefits and will be explained by showing the features of the PC system, step by step, as follows.

2. Operating Principle

It is known how a pump primes, generates pressure and how the flow is transfered to the discharge side.
However, the PC system is more than a pump and even handles LPG at vapour pressure conditions in suction lift operation.

From the general understanding of physical laws and pump technology priming of liquids in a boiling state is impossible.



Nevertheless the system works perfectly and is extremely reliable, not because physical laws have been outwitted...but applied !

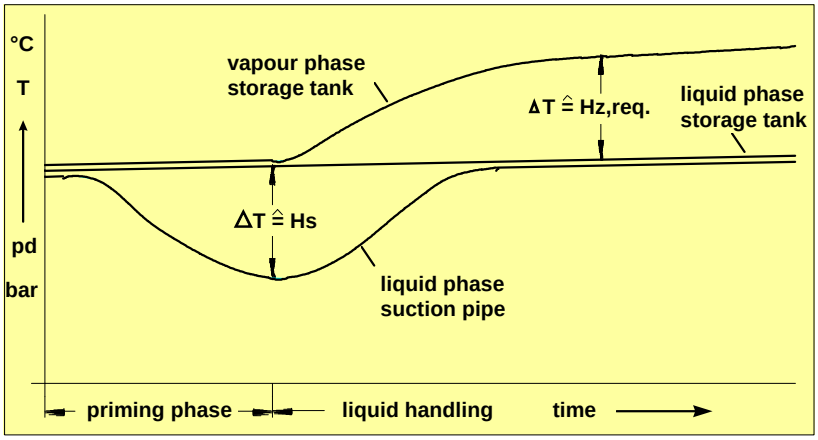
dispenser station with underground tank and top-mounted PC pump system

The operating principle is as follows:

Priming
After start-up the pump primes vapour out of the suction line. By the exhausting of vapour and re-vaporization during the suction phase heat is drawn from the liquid in the suction pipe and lowers the temperature and pressure in the suction pipe.
The pressure difference generated against the constant tank pressure causes the liquid to rise up to the pump and pumping commences.

Operation

At the same time an energy-bearing partial flow is returned to the vapour phase of the tank at a slightly higher temperature which increases the vapour pressure which then overcomes the suction lift require-ment of the pump.



temperature/pressure course at suction lift operation

The operating prin-ciple of the PC sy-stem can be seen by refering to the pressure / tempe-rature diagram with the pressure / temperature cour-se during priming and operation.

At start-up the pump is initially filled with LPG and the pressures and temperatures are exactly the same at

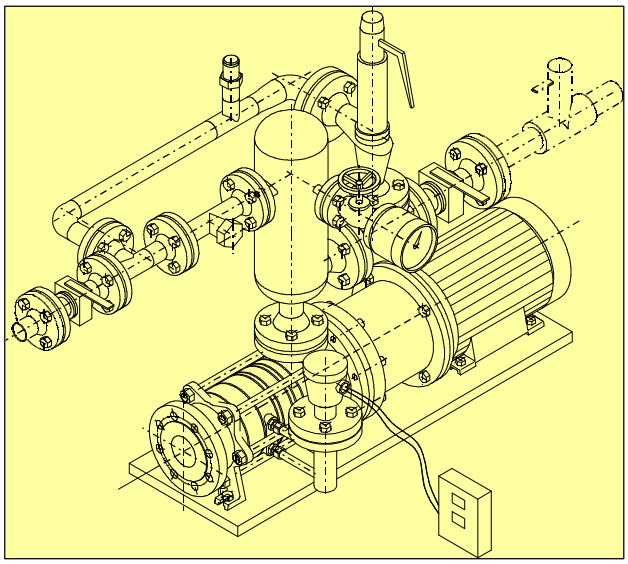
vapour phase storage tank
liquid phase storage tank
liquid phase suction pipe

The pump starts to prime and the temperature and pressure drop in the suction line and causes the liquid to rise up to the pump and pumping commences.
Now an energy-bearing partial flow is returned to the vapour phase of the tank and increases the temperature / pressure in the vapour phase above vapour pressure of the liquid and forces the liquid to climb up to the pump level.
This small continuous by-pass is fed from the pump to the vapour phase to maintain a higher vapour phase pressure at all times to ensure bubble-free LPG handling.

The limits of the system are

tank volume:	≤ 200 m³
suction lift:	≤ 4 m

propane: ≤ 100 %
propane / butane: ≥ 20 / 80
flow rate: ≤ 35 m³/h



top-mounted PC system

The PC system consists of the following main components:

- pump with dry-running protection and amplifier
- motor (explosion/flame-proof)
- gas separator
- pressure gauge
- discharge connection with ball valve
- bypass valve with return line and relief valve
- return line with orifice, check valve and ball valve

3. Pump Selection - Performance Requirements

In order to select the right size pump, the performance requirements and operating conditions must be considered carefully.
An undersized pump delivering a too low flow rate to the dispenser will mean lost revenue due to fewer cars being filled.
An oversized pump will occur higher initial costs, increased running costs and could operate at an unfavourable duty point (NPSHR/BHP).

The criteria for selection of the right pump size are:

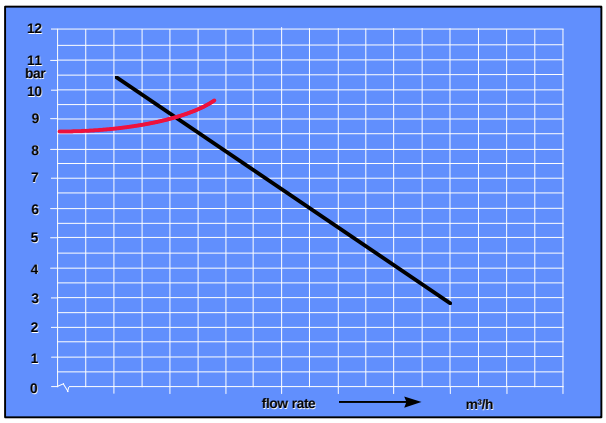
- required differential pressure at start-up
- differential pressure during filling
- dispenser filling flow rate

The differential pressure during filling and the dispenser filling flow rate are linked together.

The differential pressure at start-up is a different story and not related to any flow rate. It is a momentary condition at start-up only but the pump must be capable to generate that pressure.

At start-up the pump has to overcome the resistances in the discharge side:

- apparatus in the piping
- apparatus in the dispenser
- counterpressure in the car tank due to high ambient temperatures

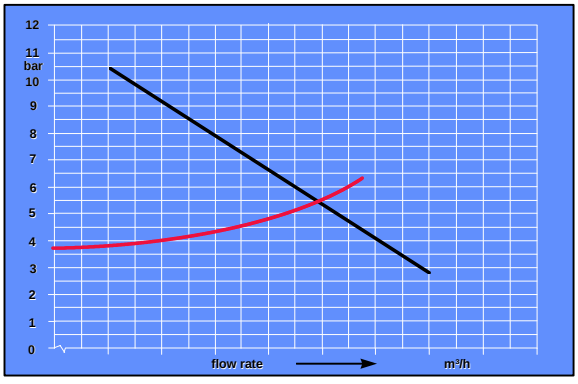


duty point at start-up

The pressure collapses immediately after filling has started but it is of major importance that the pump is capable of generating this start-up differential pressure within its performance range.
A differential pressure of 9 bar covers the most unfavourable temperature conditions.

During filling operation the pump has to overcome friction in the discharge line, the resistances of dispenser equipment and filling nozzles.

In most cases the friction loss in the discharge line is neglectable.
Depending on the brand and type of dispenser the required differential pressure is in the range of 5 - 6 bar at dispenser filling flow rate.



The selection will be based on an average filling pressure of 5,5 bar.

The deviation of the dispenser filling flow rate in case of slightly higher or lower filling pressures can be ignored because of the steep performance curve of the assigned pump.

diff. pressure during filling

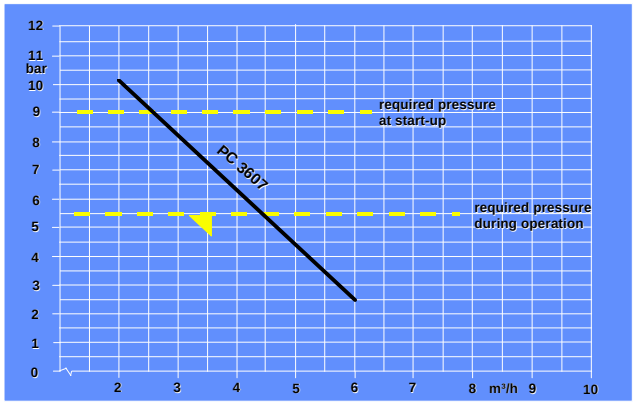
After the required pressures

- 9,0 bar differential pressure at start-up
- 5,5 bar differential pressure during filling operation

have been fixed the dispenser filling flow rate and pump flow rate have to be calculated.
The dispenser flow rate should cover the minimum requirement of at least 30 l/min per nozzle.

a) One dispenser with two nozzles

For a dispenser with two nozzles, which is the standard, the dispenser flow rate must be at least 60 l/min = 3,6 m³/h.

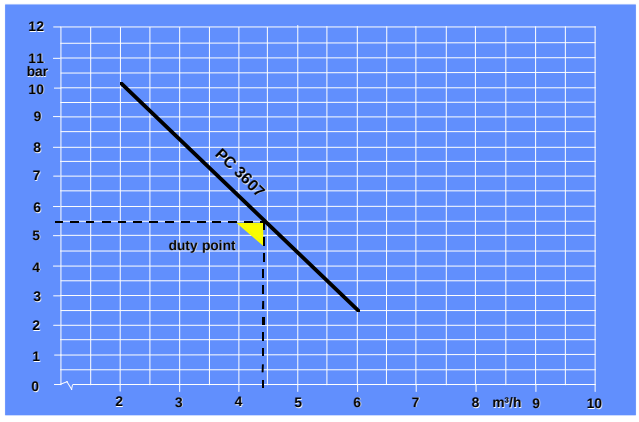


filling performance for two nozzles

The graph shows the min. duty point at 3,6 m³/h and 5,5 bar and the required diff. pressure at start-up of 9 bar.

The selected pump size PC 3607 meets the required duty point and the start-up diff. pressure.

During filling operation the actual duty point of the PC unit 3607 moves to a differential pressure of 5,5 bar and a dispenser filling flow rate of 4,4 m³/h = 73,3 l/min for two nozzles, i.e. 36,7 l/min per nozzle.



filling performance for two nozzles

However, in reality there are very few cases where two nozzles are in operation simultaneously.
Considering the required time to connect the nozzle to the car tank, to disconnect it and to pay at the cashier leads to an average filling operation of 1,5 nozzles with an

average dispenser filling flow rate of 48,9 l/min per nozzle.

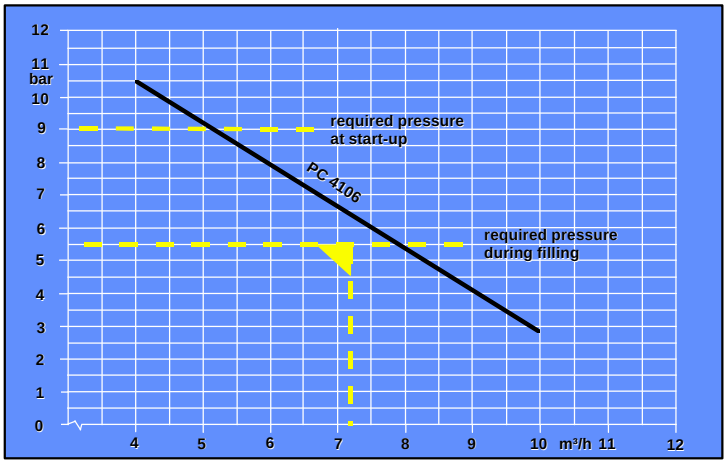
b) Two dispensers with four nozzles

In case of two dispensers with four nozzles in total the performance requirement of the flow rate changes.

Pressure requirements remain the same:

- start-up pressure at 9 bar
- filling pressure at appr. 5,5 bar

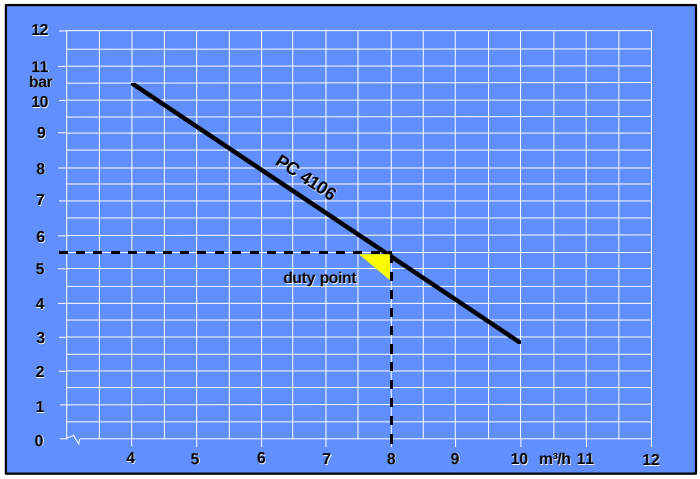
Based on a dispenser filling flow rate of at least 30 l/min per nozzle the pump has to deliver at least 4 x 30 l/min = 120 l/min = 7,2 m³/h to the dispensers.



filling performance for four nozzles

The selected pump size is a PC unit 4106. The performance curve crosses the required pressure curves.

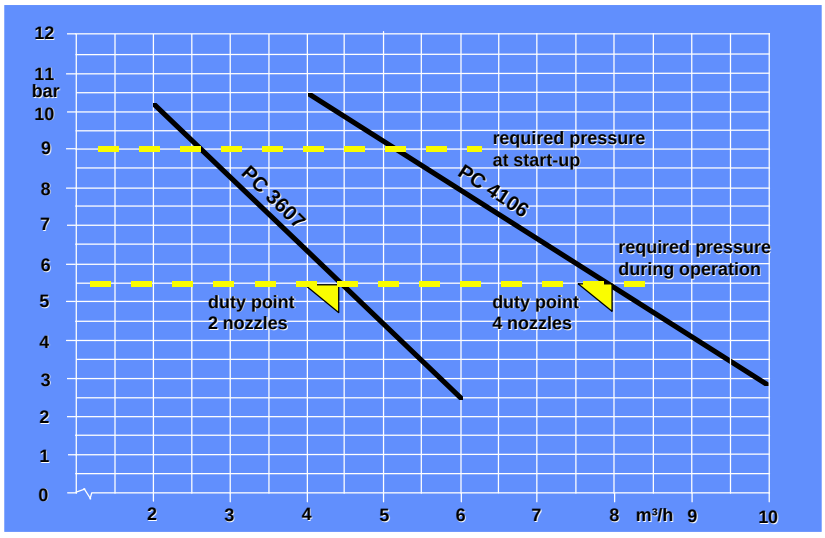
During filling operation the actual duty point of the PC unit 4106 moves to a differential pressure of 5,5 bar and a dispenser filling flow rate of 8,0 m³/h = 133,3 l/min for four nozzles, i.e. 33,3 l/min per nozzle.



duty point PC 4106

However, in reality there are very few instances where all four nozzles are in operation simultanously. Considering the required time to connect the nozzle to the car tank, to disconnect it and to pay at the cashier leads to an average filling operation of 2,5 nozzles with an

average dispenser filling flow rate of 53,3 l/min per nozzle.



Although bigger pump sizes are available to feed even more than 4 nozzles it is not recommended because most of the operating time those pumps would be oversized and operate uneconomically.

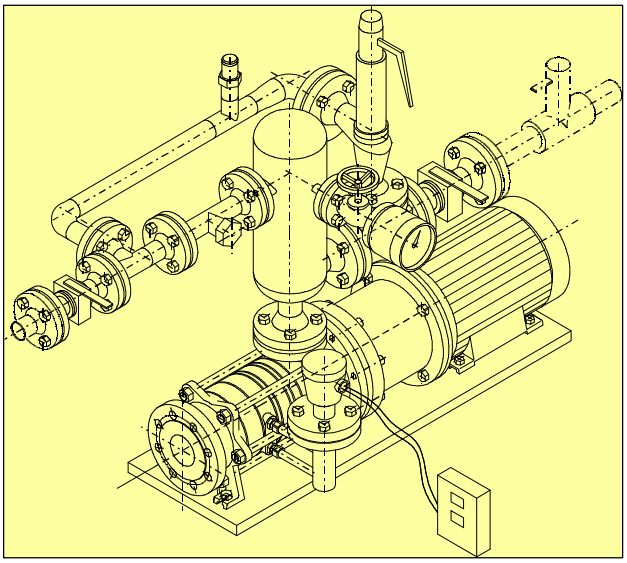
up to two nozzles: PC 3607/up to four nozzles: PC 4106

4. Components

In addition to the hydraulic requirements of the filling flow rate performance one must also consider the engineering requirements to create a reliable LPG system.

The design and dimensions of the piping have to comply not only with the safety standards but with the special demands of handling LPG with a side channel combination pump in suction lift operation as well.

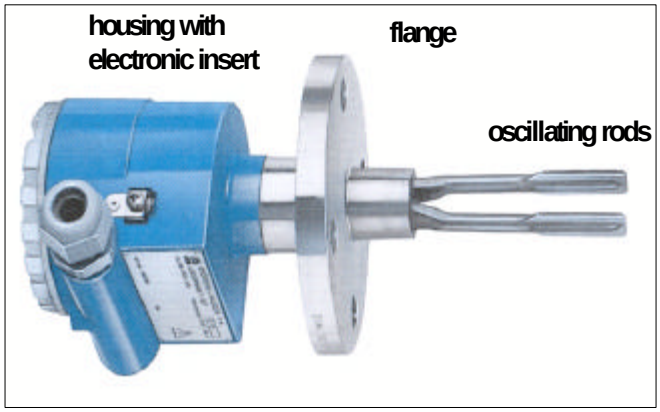
It is of basic importance to know the main components of the system and their functions.



PC unit

The system consists of:
SC combi pump CEH
motor (explos.-/flame-proof)
base plate
flexible/magnetic coupling
gas separator
bypass valve
check valve
relief valve
pressure gauge
2 ball valves
piping
dry running protection

After the pump the dry running protection device is the most important component of the system.
It is fitted directly into the retaining stage of the pump to detect the liquid level inside the pump casing.



dry running protection

It not only protects the pump against dry running but also keeps the pump in a primed condition. The dry running protection is explosion proof and designed to operate in hazardous areas.

The wiring scheme for automatic operation will be provided with the PC system.

It's of major importance for the priming and the operating reliability of the system to follow the guidelines of this wiring scheme.

Any simplification of this well approved scheme may lead to system failures.

The functions of the control panel are

- If there is no liquid in the pump, it is impossible to start the pump
- If the pump has service liquid, it will start to prime, but will be switched off if the unit is not primed within 30 sec
- If during stand-still the liquid level in the pump drops below the centerline, the pump will be switched on automatically to prime the pump and then continues operation for 10 sec

The contents of the control panel consists of relays, timers, fuses and the amplifier of the dry running protection.
It is easy to install and to connect the control panel to the dry running protection device and to the main switch board which is also outside the hazardous area.

outer and inner view of control panel

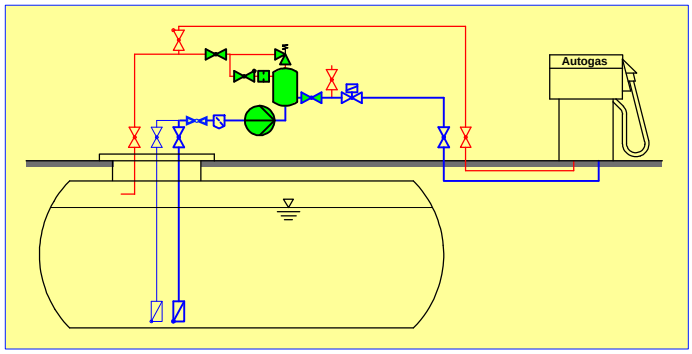
There are only a few electrical components:
switch for control power supply
main fuses
motor relay with overload protection
two switch relays
two timer relays
amplifier

Correct wiring of the control panel will ensure a reliable, trouble free, automatic operating system.

5. Installations

There are different installation requirements on site and the top-mounted PC unit has to comply with them.

a) Different tank diameters
The standards for LPG tanks vary in a lot of countries, therefore it must be possible to adapt the pumping system to the different tank diameters.



Inside the pressurized tank the top mounted PC unit requires only a suction pipe which can easily be adapted to all tank diameters, if the suction lift does not exceed 4 m.

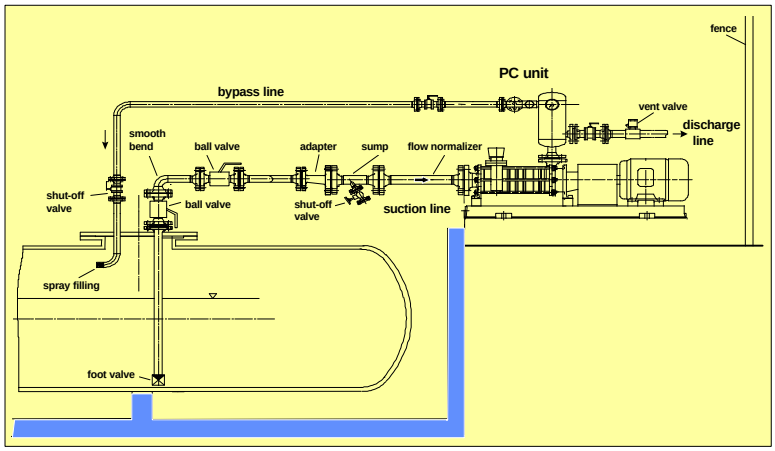
top mounted pump installation

In case of a submersible pump changes of the pump barrel will be necessary and in case of a vertical tank pump even the pump length must be modified.
With the top-mounted PC system the pump unit always remains the same because the adaption to different tank diameters is limited to the suction line.

b) One pump for two tanks
Another advantage of the top-mounted PC unit is the fact that one pump only will be needed for two tanks in comparison to submersible pumps when each tank must be equipped with one pump.

The second tank can be installed at a later time when increasing turnover of LPG requires a higher storage capacity.

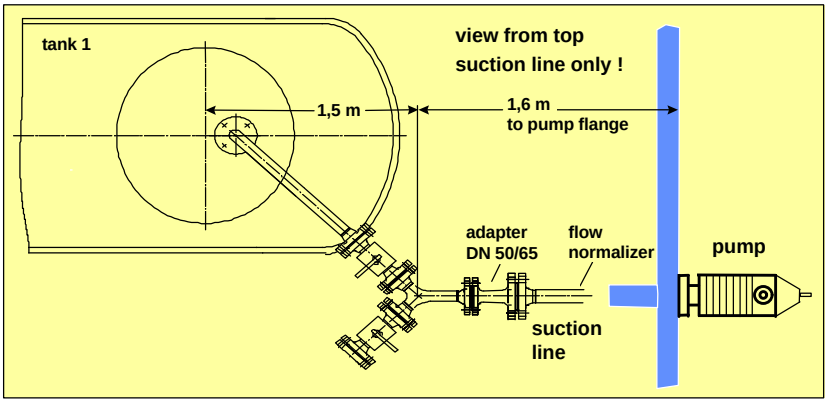
Also in remote areas the installation of a second tank can be of bene-fit because the number of truck drives for refilling can be reduced and cut costs.



installation proposal

The drawing shows an installation proposal for a PC unit.

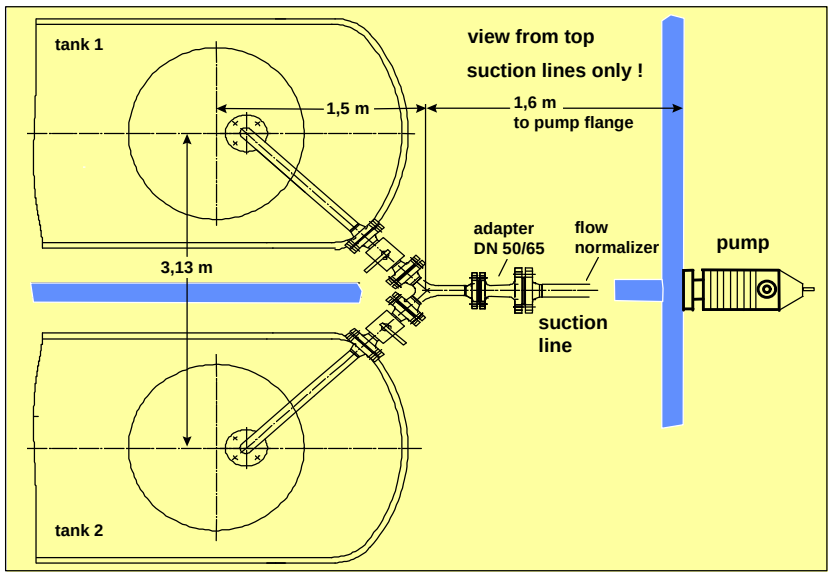
The design of the suction pipe is of major importance for the performance and reliability of the system.



1pump/1 tank and option of a second tank

The first tank has to be installed parallel to the pump axis. The horizontal part of the suction line is connected to the main suction line with a y-piece.

The initial installation costs are not higher than for a standard installation with one tank /one pump and an underground tank in line with the pump axis.



1 pump for two tanks

Should there be a future requirement to double the storage capacity then it is very easy to install a second tank and add a second suction line and by-pass line to the existing system.

The advantage of installing a top-mounted PC unit is that it can be used with two tanks with very minor modifications.

The initial costs for a one tank installation are kept low. When extending the system to two tanks the existing installation remains un-touched. The only addition investment will be in a small amount of pipework.

Huge savings over submersible equipment!

6. Benefits

Besides the operating reliability more and more economical reasons determine the choice of the pumping system.

The following points are of substantial importance:

initial costs
long-term operating costs
lifetime of the pumping system
maintenance
down-time periods (stand-still of pump during tank refilling)

a) Initial costs

The comparison of the initial costs has to include the complete package.

The costs for the PC unit cover the pump unit, all valves, the piping and the dry running protection with amplifier.

	station with 1 tank		station with 2 tanks	
	Sterling SIHI	submersible pump	Sterling SIHI	submersible pump
pump / PC plant	100 %	70 %	100 %	140 %
accessories	---	10 %	---	20 %
pump chamber	---	30 %	---	60 %
total costs	100 %	110 %	100 %	220 %

Comparison of installation costs

A submersible pump only is cheaper but if the costs for the additional equipment, in particular the pump barrel, are added then the total costs are higher than for a PC system.

The comparison is even more impressive for a station with two tanks.
A two tank system will need two submersible pumps compared to only one PC unit.
The benefit for the customer with a top-mounted PC unit is the versitility of the system. One pump for up to two tanks and up to four dispenser nozzles keep the initial costs low and requires little investment in case of extension work at autogas stations.

The benefit is obvious, drastically reduced costs in favour of the PC unit.

b) Operating costs and loss of revenue

Other aspects to consider are the operating costs and the loss of revenue.
For liquids at vapour pressure submersible pumps need a certain feeding head (min. tank level) to avoid cavitation which leads to a loss of performance, increased wear and finally to repair or replacement.
Due to severe cavitation of some submersible pumps which at the inlet side are not de-

	Sterling SIHI PC System	Submersible Pumps
	2 tanks of 20 m³- 1 pump	2 tanks of 20 m³- 2 pumps
max tank level	85 %	85 %
min tank level	5 %	30 %
utilized tank volume	80 % = 32 m³	55 % = 22 m³
daily consumption	10 m³	10 m³
quantity lasts	3.2 days	2.2 days
tank refilling after	3 days	2 days
refillings per year	120	180
	60 truck drives less!	
refilling time	1.5 hours	1 hour
lost revenue based on 16 operating hours and 10 m³/day	----------	(10:16)x180 x 0.5=56.25 m³ 56,250 l x 10 RS = 562,500 RS/year

signed to the requirements of LPG it is recommended to limit the min. tank level to 30 % which reduces wear partially but considerably under-utilized the LPG tank capacity.

Comparison of operating costs

Refilling must be done more often and at the end of the year an extra 60 truck deliveries would have been necessary if submersible pump were used.

During refilling the submersible pump must be stopped and no LPG will be sold during that period. The PC unit can still be operated during tank filling.

The effect will be shown by an example for India.
Calculations based on an LPG cost of 10 Rupees/litre suggest that by using a submersible pump the operator will loose approximately 562,500 Rupees revenue per year which is converted to European currency a price of 0,25 Euro/litre and a loss of revenue of more than 14 000 Euro per year.The same amount will be saved by installing a PC unit.

The reliability and the high dispenser filling flow rates of PC units guarantee a fast return of money. Dispenser filling operation even during refilling of the storage tank avoids the loss of revenue.

c) Maintenance and lifetime

The arrangement outside the tank gives easy access for maintenance, although minimal maintenance is required.

benefit for customers

- **1 pump for 2 tanks and up to 4 dispensers**
  → ***lower initial costs !***
- **high and guaranteed dispenser filling rates**
- **reliable priming and operation**
- **easy access for maintenance**
- **minimal maintenance**
- **long lifecycle**
  → ***lower operating costs !***
  → ***no loss of revenue !***

Advantages of top-mounted PC system

Due to proper operating conditions the MBF time and lifetime of the pump unit are extremely high. It can be expected that first maintenance will be necessary at the mechanical seal after more than 5 years of operation.

7. References (Extract)

size	application	customer	country
◆PC 3607/7	autogas	SHELL-Melbourne	Australia
◆PC 3605/7	autogas	Petronas-Kuala Lumpur	Malaysia
◆PC 3605/7	autogas	BP-Brussel	Belgium
◆PC 3607/7	spray can	L'Oreal-Karlsruhe	Germany
◆PC 4106/7	autogas	AYGAZ-Istanbul	Turkey
◆PC 4106//7	autogas	CNPC-Beijing	China
◆PC 3103/7	vaporizer	BP-Athens	Greece
◆PC 3607/7	autogas	BORAL GAS-Brisbane	Australia
◆PC 3104/7	air con fill.	AUDI-Rüsselsheim	Germany
◆PC 3605/7	autogas	PTT-Bangkok	Thailand
◆PC 3605/7	autogas	ESSO-Bangkok	
Thailand			
◆PC 3607/7	autogas	MOBIL-Croydon	Australia
◆PC 3605/7	autogas	Yijan Estate-Beijing	China
◆PC 3607/7	autogas	SHELL-Sydney	Australia
◆PC 4106//7	autogas	AYGAZ-Istanbul	Turkey
◆PC 6103/7	loading	TYCZKA-Munic	Germany
◆PC 3605/7	autogas	SHELL-Huy	Belgium
◆PC 3607/7	autogas	BORAL GAS-Sydney	Australia
◆PC 4106/7	autogas	IPRAGAZ-Istanbul	Turkey