SPE 40006

Optimizing Field Compressor Station Designs

Kent A. Pennybaker / River City Engineering, Inc.

Abstract

The main reasons for optimizing new field compressor station designs and for upgrading existing stations are safety considerations, environmental impacts, and economics. With a well designed compressor station it is possible to improve safety and environmental conditions while saving capital and increasing income.

A well designed compressor station will be able to reduce the venting of heavy hydrocarbons from storage tanks, which can increase safety by reducing the possibility of forming explosive vapor clouds near venting tanks. An optimized design can improve safety by reducing the amount of hydrocarbon inventory located at the site. This can also save money by eliminating the need for a site to be covered by OSHA's Process Safety Management.

Improving the environmental conditions by reducing the venting of hydrocarbons from the station's storage tanks is another advantage of a well designed compressor station. The exhaust pollution can also be reduced by utilizing less compressor horsepower and reducing the trucking needs for station supplies and products such as methanol and condensate.

The economic advantages of an optimized compressor station include reduced operating costs and maximized product recovery. Reduction in operating costs are achieved through fuel savings from reduced horsepower requirements and reducing trucking costs. Maintenance activities are also typically less due to less horsepower, freeze ups, etc. Reducing the venting requirements means more gas is recovered as product, resulting in more income.

Evaluating and selecting the best configuration for a compressor station design is an important decision. Many schemes have been evaluated for different situations and compared so that the most cost effective configuration can easily be selected for new or existing station designs.

Introduction

Many compressor stations consist of one to four stage skid mounted compressor packages linked together by common headers. Operating pressures for these compressor stations range from a slight vacuum at the suction to discharge pressures over 1000 psig.

A typical compressor station design may consist of an inlet separator to collect liquids and slugs that may have formed in the gathering system pipeline. From there, the gas is sent to the compressor skid(s) where it is compressed. At the discharge of each stage the gas is cooled, typically with an air cooler, and then it passes through a scrubber before passing to the next stage or to the discharge pipeline.

The liquids collected from the scrubbers are handled a number of different ways. A typical simplified approach is to route the liquids from the scrubber level control valves to a low pressure tank. This process is referred to as the LP Tank scheme (**Fig. 1**).

The LP Tank can be a pressure vessel operated at a relatively low pressure (atmospheric to ~25 psig) or it can be a simple industry standard "210 tank" (atmospheric tank with 210 bbls of capacity). In either case, the vapors produced from the flashing liquids are vented to the atmosphere. The low pressure condensate is periodically trucked out and sold.

Efficient and safe handling of the liquids collected from the scrubbers in a compressor station is one of the keys to a good design. Poor handling of these liquids can be the major source of operating problems and have a significant impact on the station economics.

There are three main concerns that should be addressed in the liquid handling design for any compressor station: safety, environmental impacts, and economics. An additional point of consideration should be operability, which includes things like hydrate formation, failure consequences, etc.

Process Definitions

The goal of this paper is to illustrate to the designer/ operator of compressor stations the advantages of good process engineering in the design of compressor stations. There are many process schemes that can be employed for a compressor station design. Each has its distinct advantages over the others depending upon the design conditions (gas composition, pressures, etc.).

Each process should be evaluated and compared to others to determine the "optimum" process for the application. Four processes are presented in this paper and compared showing the pros and cons for each process. These examples should aid the designer in their initial screening of processes for a new application.

LP Tank. The LP Tank scheme discussed above is probably one of the most typical compressor station designs. It can be referred to as the industry standard and will serve as the basis for most of the comparisons in this paper.

The advantages of the LP Tank scheme are that it is simple and cheap to install. It can also typically avoid OSHA's Process Safety Management (PSM) regulation since the bulk storage is operated at atmospheric pressure.

The typical disadvantages are venting, cold temperatures, large shrinkage, and poor compression efficiency. These disadvantages do not apply to all applications. In some cases, however, they can be extreme.

High hydrocarbon venting rates are a safety and environmental concern and a primary cause for poor compression efficiency. The hydrocarbons that are vented can form vapor clouds which could be ignited. The vented hydrocarbons are lost to the atmosphere and result in no value gained as either condensate or gas. This can contribute to a large gas shrinkage across a compressor station.

The flashing of liquids from high pressure scrubbers across the level control valve and into the LP Tank can result in operating temperatures significantly below -20 °F, which is the typical minimum allowable operating temperature for normal carbon steel. At temperatures below -20 °F, carbon steel becomes brittle and can easily fail due to vibration or stress.

Level control valves from high pressure scrubbers can fail open either through freeze-up or mechanical problems. This can result in very large blow-by rates which lead to large gas releases and in some cases catastrophic tank failure.

HP Tank. The HP Tank scheme (**Fig. 2**) is similar to the LP Tank scheme, except that the liquids from the higher pressure scrubbers are routed to a high pressure storage vessel (HP Tank). The HP Tank operates at a pressure greater than the inlet pressure (typically 30 to 200 psig) so that any vapors produced from the HP Tank can be routed back to the suction of the compressor station. Both a low pressure and a high pressure condensate are produced and must be trucked out.

The HP Tank scheme has many advantages over the LP Tank scheme. It eliminates most of the atmospheric venting and thus gas losses.

It also maximizes condensate production at the compressor station. This can also be a disadvantage because it leads to more trucking costs. This is further complicated by having to truck both low and high pressure condensate, which may involve multiple trucking companies and market outlets. Single product trucking can be accomplished by pumping the low pressure condensate into the high pressure condensate storage. However, this adds cost for the pumping equipment.

Handling of the high pressure condensate does increase the safety risk over handling of just low pressure condensate. The storage of high pressure condensate can also lead to the station being regulated by PSM.

The HP Tank scheme is also more expensive than the LP Tank scheme, but can typically easily pay for itself in the reduced gas losses. The cost of PSM compliance must also be considered if applicable.

HP Scrubber. The HP Scrubber scheme (**Fig. 3**) is very similar to the HP Tank scheme, except there is no high pressure condensate storage or trucking. This results in a number of advantages over the HP Tank scheme, with only a few disadvantages.

Since no high pressure condensate is stored or trucked the concern over high pressure condensate handling is nearly eliminated. The lack of high pressure storage could result in avoiding PSM regulation. This scheme will be cheaper to build and install than the HP Tank scheme, but still slightly more than the LP Tank scheme. Condensate handling is significantly simplified since only one product must be stored and trucked out.

The HP Scrubber scheme does result in some atmospheric venting, but significantly less than the LP Tank. This does lead to some gas losses that can affect the station economics.

Cascade Recycle. The Cascade Recycle scheme (**Fig. 4**) differs considerably from the previously described schemes. In this process the liquids from each scrubber are routed back to the next lowest operating pressure scrubber within the compression sequence. Only the inlet scrubber liquids are then routed to a low pressure condensate storage tank.

This process has proven to have many advantages in most compressor station applications. These advantages include low capital cost, only low pressure condensate handling, minimization of liquids produced, and thus maximization of gas output from the station.

The capital cost is comparable to that of the LP Tank scheme. Only low pressure condensate storage and trucking is required.

This process typically results in the minimization of liquids produced, or consequently, a minimization of gas shrinkage across the station. This means that a richer gas is discharged from the station and sent via a pipeline a processing plant downstream. The compression efficiency is typically better than others as measured in terms of hp/MMSCFD.

Another advantage is that since only low pressure condensate is stored, the station can usually avoid being PSM regulated.

This process can result in atmospheric venting if atmospheric tanks are used for the low pressure condensate storage. However, it is significantly less than the either the LP

Tank scheme and less than the HP Scrubber scheme. The use of a low pressure "bullet" can eliminate the venting.

Another disadvantage is the implementation of this scheme to rental or other existing units. Early planning and involvement is necessary to incorporate the necessary piping changes that are different from typical piping configurations.

Process Comparisons Through Examples

Two examples cases were simulated to illustrate the differences in performance of the different processes. The first case is a three stage high pressure compressor station and the second case is a three stage low pressure compressor stage. Both cases are compressing relatively rich gas, which is where typically the liquid handling problems are of the greatest magnitude.

The four process schemes were simulated using the HYSIM™ process simulator. The inlet gas was saturated with water at the inlet conditions. The inlet temperatures were 60 °F and the interstage temperatures were 80 °F. This is relatively cool for interstage temperatures, but is typical in some winter time climates without good louver control. These low temperatures also increase the magnitude of the example cases.

In all cases the amount of water condensed through the compression train is the same. The amount of water is a function of the operating pressures and temperatures and is not affected by the "process".

Three Stage High Pressure. The inlet gas rate was 45 MMSCFD of relatively rich gas (8.70 C2+ gal/MCF). The inlet pressure was 100 psig, and the discharge pressure was 2200 psig. The results for the four schemes are compared in **Table 1**. This example clearly highlights the differences of each scheme. A careful analysis is required that considers the economic contracts in place, the capital costs, and the safety and environmental effects.

Although the LP Tank scheme utilizes the least amount of horsepower, it also results in the least amount of outlet (residue) gas (39.17 MMSCFD) entering the downstream pipeline. It also produces the second lowest output of condensate (1772 BPD). These two factors lead this scheme to have the highest atmospheric venting rate (3410 MSCFD) of all the schemes (over four times higher than any other).

The HP Tank scheme results in no atmospheric venting and in this case no low pressure condensate. Therefore, only HP condensate would typically have to be trucked.

The HP Scrubber scheme is similar to the HP Tank scheme only there is some atmospheric venting losses. Both the HP Tank and the HP Scrubber scheme have the highest horsepower requirements of the four schemes.

The Cascade Recycle scheme has the highest outlet (residue) rate (42.35 MMSCFD) and the lowest condensate rate (1628 BPD). This can be an advantage if the goal is to get the gas to a plant to recover the liquids. It reduces the amount of trucking and handling required.

The Cascade Recycle scheme also results in the best compressor efficiency requiring only 185.9 horsepower per MMSCFD of discharge gas.

Metallurgy temperature and hydrate problems are anticipated for the LP Tank. The HP Tank, HP Scrubber, and Cascade Recycle schemes avoid the metallurgy problems and the hydrate problems are also minimized.

Three Stage Low Pressure. The inlet gas rate was 5 MMSCFD of relatively rich gas (7.95 C2+ gal/MCF). The inlet pressure was 14.5 psia and the discharge pressure was 275 psig. The results for the four schemes are compared in **Table 2**. This example again highlights some of the differences between the four schemes. Again a careful analysis is required to determine which scheme best meets the needs for a new compressor station.

The Cascade Recycle scheme utilizes the most horsepower, although it is only slightly higher (3 hp, 0.3%) than the other schemes. However, the Cascade Recycle process produces the least amount of condensate (3.8 BPD) and thus the least amount of shrinkage across the compressor station. Also, due to the low inlet pressure, there is no atmospheric venting from this scheme.

The LP Tank scheme has the highest atmospheric venting rate (5.6 MSCFD) by a factor of almost three.

The HP Tank scheme has the highest condensate production (7 BPD). Again in this example, no LP condensate was produced, therefore, primarily only one condensate product has to be trucked out.

The HP Scrubber scheme is similar to the HP Tank scheme with slightly less condensate (5.6 BPD of LP condensate) production and a small amount of atmospheric venting (1.9 MSCFD).

Field Experience

Some past experience is used to highlight how two compressor stations were optimized through a process evaluation. In one case it was an existing compressor station that was experiencing a lot of operating problems. The other example shows how a quick investigation resulted in a optimized station design.

Existing Station. An existing three stage high pressure compressor station configured in the LP Tank scheme was experiencing a lot of problems. The condensate was routed and stored in an atmospheric "210 tank". The station was experiencing high venting rates creating a "visible" vapor cloud at times around the tank. The venting rates were so high at times that liquid carryover had occurred and was visible as stains on the side of the tank.

A look at operating conditions via simulation also showed that the operating temperatures was well below -20 °F at times, exceeding the minimum temperature rating of carbon steel. The primary concern at this station was that of safety. Of course the environmental problems were clearly visible.

A quick study was completed that evaluated different schemes. The study showed that any of the other schemes would significantly reduce the venting and metallurgy problems, while increasing the revenue streams. Ensuing discussions, however, eliminated the Cascade Recycle process since the compression skids were rental units and it would be difficult and costly to get the rental company to modify the skids. The HP Tank scheme was not favorable due to the added burden of making the site a PSM regulated facility. Therefore, the HP Scrubber process was selected and installed.

The HP Scrubber process significantly reduced the atmospheric venting. It also eliminated the excessively cold temperatures which jeopardized the carbon steel metallurgy. As an added plus, it reduced the hydrate problems associated with such cold operating temperatures when the liquids flashed. All these items improved the safety and environmental aspects of the station. As an added bonus, the modifications paid for themselves with a modest rate of return, by increasing the condensate recovered and sold from the station and reducing the gas shrinkage across the station resulting in more gas available for processing and sale.

New Station. A new three stage high pressure compressor station was proposed. Initially, the client had proposed a LP Tank design. After some simulation study work the client opted for the Cascade Recycle process due to significant advantages.

The simulation results indicate that the Cascade Recycle process utilizes slightly less horsepower (0.2%), increases the discharge gas rate (1.2%), and increased the discharge BTU content (2.7%). In addition, this process reduced the atmospheric venting significantly (98.7%) and the condensate produced and trucked slightly (36%).

In addition, further comparison showed that separator and scrubber sizes within the compression train were not affected, therefore, confirming a minimal cost of implementation.

Conclusions and Recommendations

Optimizing the design of compressor stations can result in some major benefits. A good compressor station design generally leads to an increase in safety and revenue, and a reduction in environmental impact and operating costs. All of these are positive aspects for any operating company.

With all these positives potentially to be gained, it makes good sense to examine the design of new facilities and even to re-evaluate existing facilities. Each case must carefully evaluated and all factors considered: safety, environmental, and economics.

Acknowledgments

The author wishes to thank Terryl Filip and David Scarborough of Conoco, Inc. for their help over the years in this area. Also, the author wishes to thank his colleagues, Scott Wolverton and Steve Chafin for comments and suggestions on this paper.

TABLE 1
Three Stage High Pressure Compressor Station

	LP Tank	HP Tank	HP Scrubber	Cascade Recycle
Horsepower	7553	7952	7952	7874
Discharge Rate (MMSCFD)	39.17	41.32	41.32	42.35
Discharge Composition (gal/MCF)	6.77	6.89	6.89	7.33
Efficiency (hp/MMSCFD)	192.8	192.5	192.5	185.9
Atmospheric Venting (MSCFD)	3410	0	783	497
LP Condensate (BPD)	1772	0	2113	1628
HP Condensate (BPD)	--	2605	--	--
Total Condensate (BPD)	1772	2605	2113	1628

TABLE 2
Three Stage Low Pressure Compressor Station

	LP Tank	HP Tank	HP Scrubber	Cascade Recycle
Horsepower	1056	1056	1056	1059
Discharge Rate (MMSCFD)	4.99	4.99	4.99	4.99
Discharge Composition (gal/MCF)	7.90	7.90	7.90	7.93
Efficiency (hp/MMSCFD)	211.7	211.6	211.6	212.1
Atmospheric Venting (MSCFD)	5.6	0	1.9	0
LP Condensate (BPD)	4.8	0	5.6	3.8
HP Condensate (BPD)	--	7.0	--	--
Total Condensate (BPD)	4.8	7.0	5.6	3.8

Fig. 1: LP Tank scheme employed in a typical three stage compressor station.

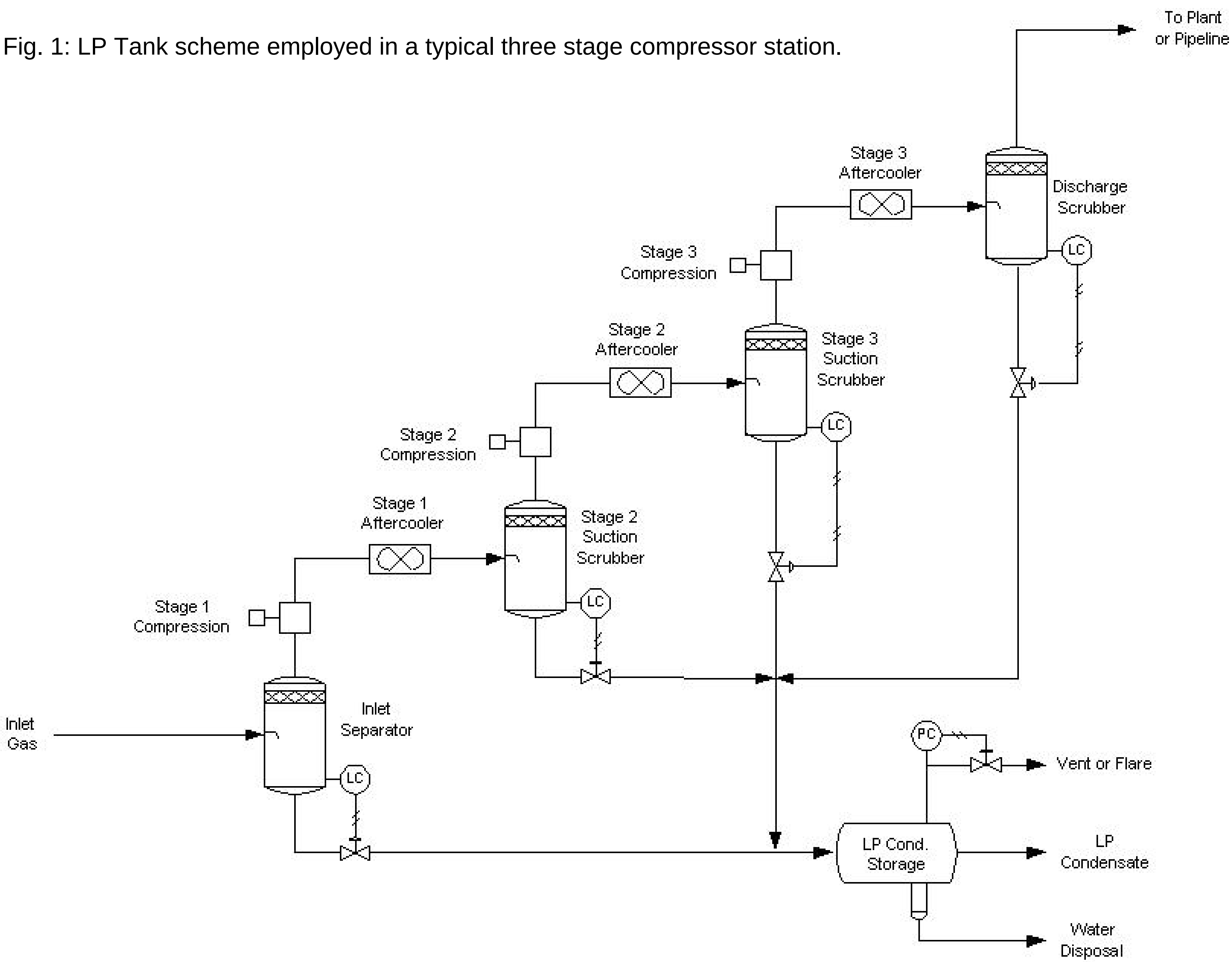

Fig. 2: HP tank scheme employed in a typical three stage compressor station.

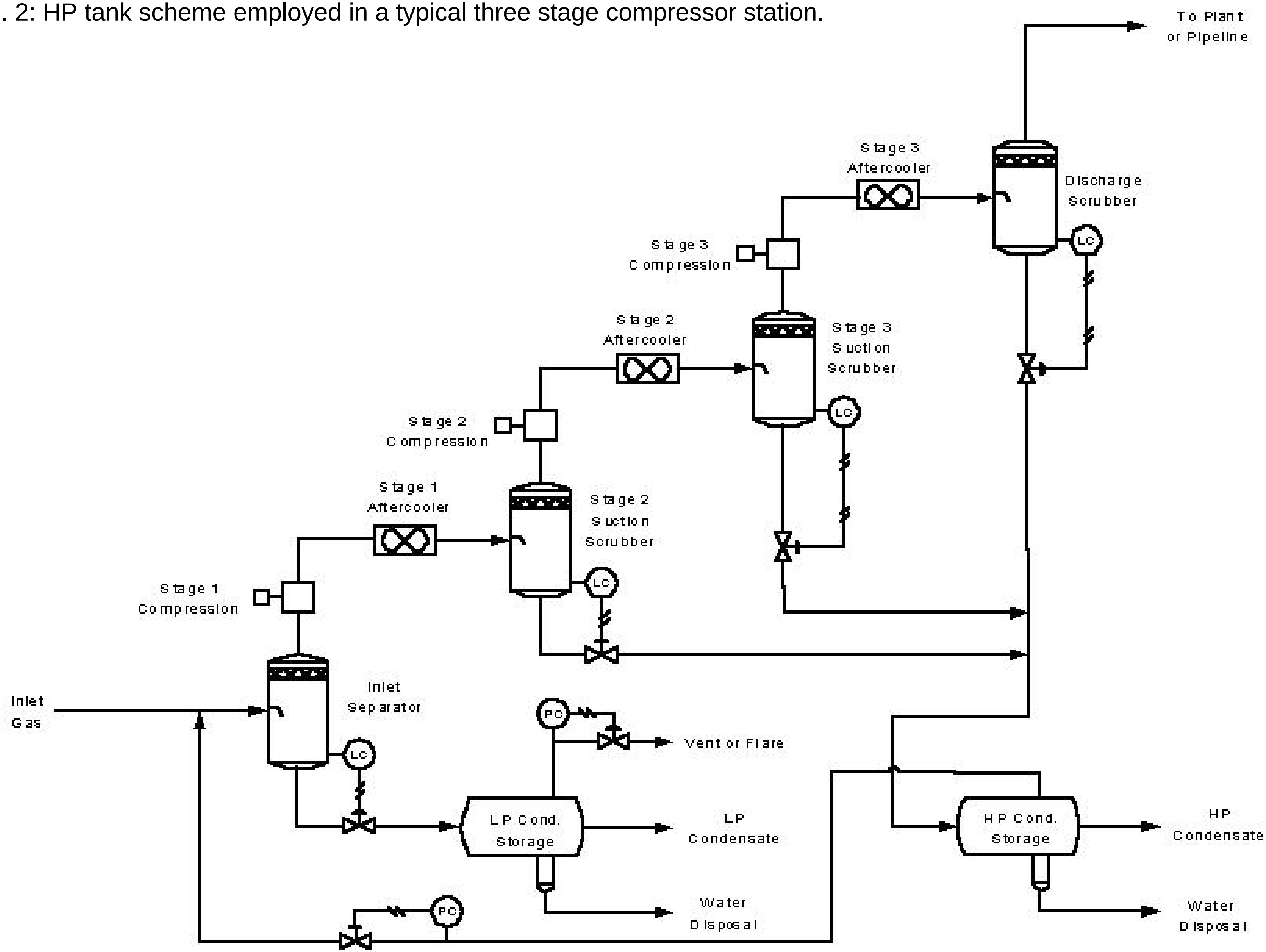

Fig. 3: HP scrubber scheme employed in a typical three stage compressor station.

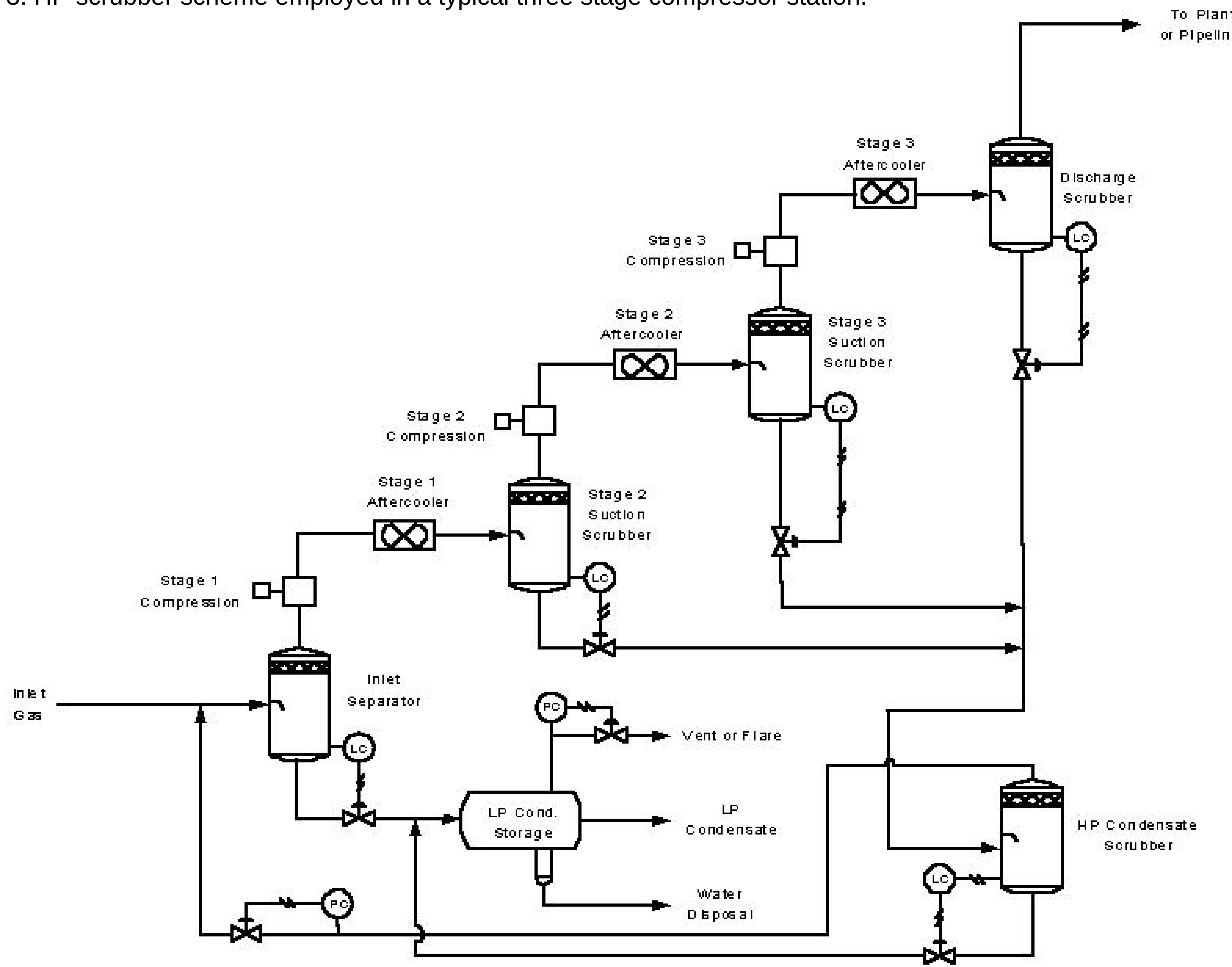

Fig. 4: Cascade recycle scheme employed in a typcial three stage compressor station.