

USING DIAPHRAGM PUMPS IN SAMPLING SYSTEMS

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Basically, a sample system consists of a means to move or transport a sample that is representative of the process stream from the sample point to an analyzer. When the sample pressure is too low, a pump is often used to facilitate this movement. The sample system will include features that maintain the sample's integrity and at the same time modify the sample conditions so that the analyzer can measure the components.

Following is a discussion of several basic aspects of sample system design. These include response time, pump location, pulsations and sample line size. Various methods to control sample pressure and flow will also be discussed.

Response time

Often it is desired to analyze the sample within a certain time frame so the analysis is closely linked to real time process conditions. This can be divided into two aspects or parts. The first part is the time required to move the sample from the sample point to the analyzer.

The second part is the time required for the analyzer to measure the sample and display the results of the analysis. The second part of the overall response time can vary greatly depending on the analyzer in use. It is the first part that will be discussed here which will be called the transport response time. The initial sample conditions, sample line size and flow rate all play a major role in determining the transport



Photo: Air Dimensions

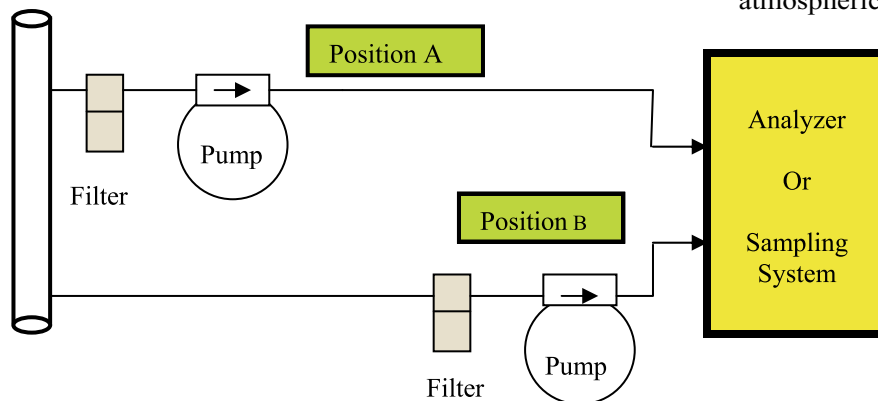


Figure 1: pump location/line size

response time. One can expect a transport response time of approximately 15 seconds for every 100 feet of sample line up to 500 feet. This assumes a standard flow rate of 5 LPM, 3/8" OD sample tube, and an atmospheric sample pressure. Tube with 1/4" OD can be used which reduces the flow rate requirements. However, pressure drop can become an issue with the smaller tube size.

Sample line size

A sample pump is required if the process pressure is too low to meet response time requirements. The location of the pump and the selection of line size are the most important factors when dealing with low-pressure samples. This may be of little concern for short line lengths, but when long distances are involved, this can be a serious and expensive mistake if not evaluated correctly.

Piping design is best illustrated by the example in Figure 1. The analyzer requires a flow rate of 8 standard liters per minute (SLPM) at an absolute pressure of 14.7 psi (= 0.101 MPa), i.e. atmospheric pressure. The process pressure is atmospheric, that is 14.7 psia, and the sample line length is 91.5 m. The filter pressure drop is assumed to be negligible.

There are two main choices to be made – (1) the sample line size, and (2) the location and selection of the pump. The effect

of the size of the sample tubing on the pressure experienced by a pump located at positions A and B in Figure 1 is illustrated in Table I. The selection of a pump for use at position A is dependent on the flow capacity of the pump where inlet pressure is atmospheric. The outlet pressure is the sample-line back pressure. Position B is dependent on the reduced pressure (or vacuum) at the pump inlet (due to sample line loss) and the required flow rate with the pump outlet at atmospheric pressure.

SIZE	I.D.	Line Press Drop - Pos A	Line Press Drop - Pos B
1/4 x 0.035" wall	0.180 inch	19.0 PSIA - 14.7 PSIA = 4.3 PSID	14.7 PSIA - 8.5 PSIA = 6.2 PSID
3/8 x 0.035" wall	0.305 inch	15.1 PSIA - 14.7 PSIA = 0.4 PSID	14.7 PSIA - 14.3 PSIA = 0.4 PSID

Table 1: effect of pump location and line size on pressure drop.

Comparing tubing pressure drops for pressurized and vacuum sample-line conditions illustrates the importance of line size.

A larger displacement pump may be required for smaller line sizes because of vacuum conditions and decreased density. Vapor condensation may be a problem if the pump is located a long distance from the process inlet and the sample pressure is reduced below the gas vapor pressure. (Remedies for this issue will be discussed in the section on heated sampling systems). It should be noted that the response time varies significantly between the two different tube sizes. The transport response time is 32 seconds for the 3/8" OD tube and 11 seconds for the 1/4" OD tube.

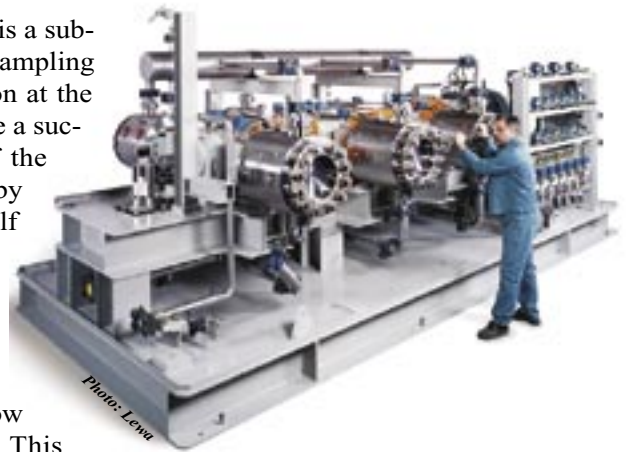
Final selection of line size and pump location is affected by many factors, including local codes, environmental considerations, system design and installation requirements.

Pump pulsations

The effect of pump pulsation is a subject not often considered in sampling system design. The connection at the diaphragm pump inlet will see a suction vacuum for one-half of the motor shaft rotation followed by 'no flow' for the remaining half of the rotation – the exhaust pulse (flow) portion of the pump cycle. Both the inlet and exhaust strokes create peak flows several times greater than the average flow rate specified for the pump. This raises several concerns for the selection of components (line size, filter, flow indicators, etc.) for optimum design. The inlet and outlet conditions are depicted in Figure 2.

Inlet pulsation

Filters are used as protective devices in most sampling systems. A filter is typically installed before the pump to



remove contamination from the sampling system. Placing the filter close to the pump inlet will have the effect of a pulsation dampener, where the inlet suction vacuum is stored in the filter body (Figure 3). This will reduce the vacuum and flow-rate peaks and increase the average pump flow rate. Overall system performance is thus improved at little or no additional cost.

Outlet pulsation

Installing a filter at the outlet will reduce the amplitude of the pump outlet pressure pulse. This is important when flowmeters or other pressure-sensitive instruments are used, as pulsations will give false readings. Pulsations can also be reduced by selecting the optimum stroke that will deliver the required performance within a basic pump size. Pumps are designed in a fashion that maximizes performance which also defines the maximum stroke of the eccentric. (The eccentric is the component of the pump that translates the rotating motion of the motor into the linear motion of the diaphragm). Some manufacturers offer pumps with lower eccentric (stroke) values to better match the performance requirements of the application. Selecting the optimum eccentric size for a given pump can reduce pulsations significantly.

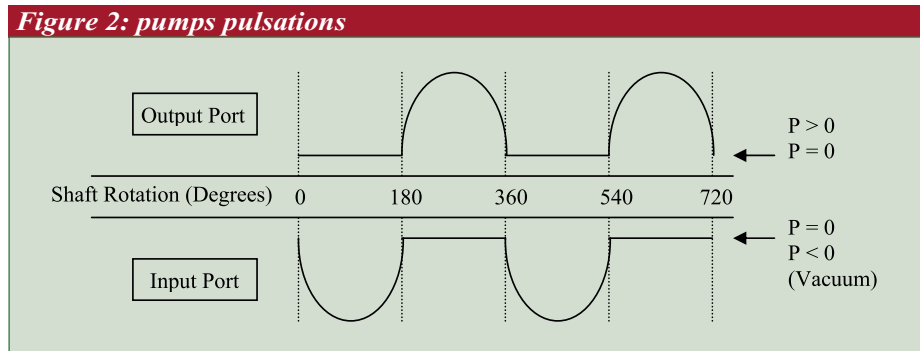


Figure 2: pumps pulsations

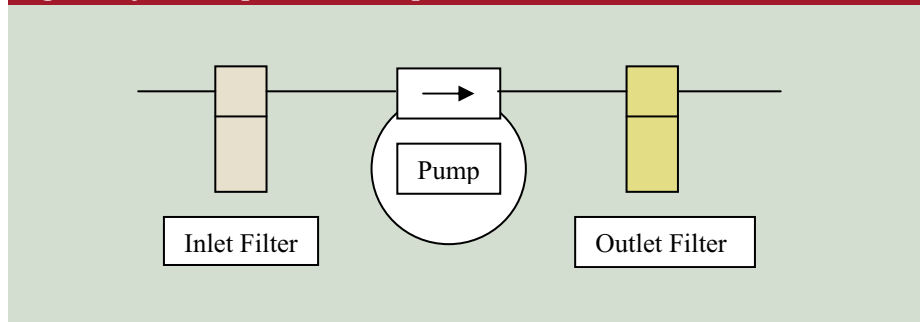


Figure 3: filters as pulsation dampeners

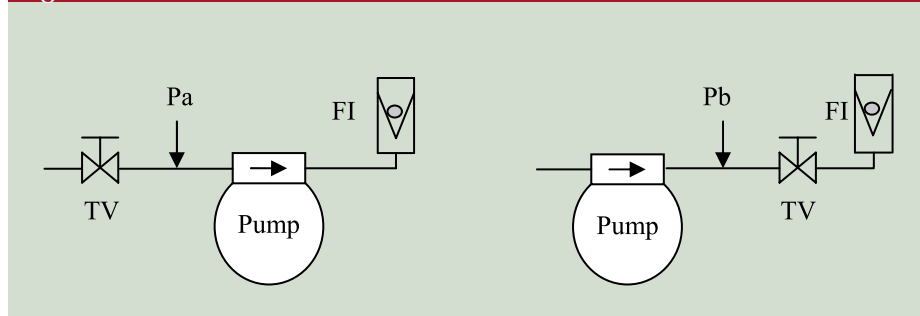


Figure 4: throttle valve location

Flow and pressure control methods

- **Control Valve:** The simplest form of flow control is a manual throttle valve (TV) in series with the pump. This may be located before the pump - configuration A - or after the pump - configuration B (Figure 4). The flow rate in configuration A is

Figure 5: flow control with relief valve

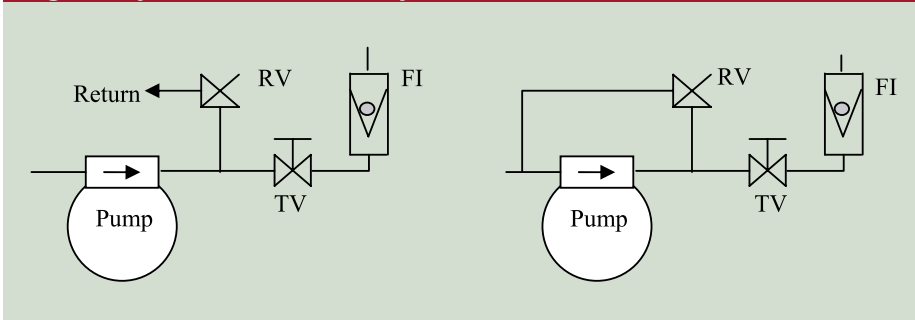


Figure 7A (right): BPR with TV after pump - Figure 7B (left): before pump

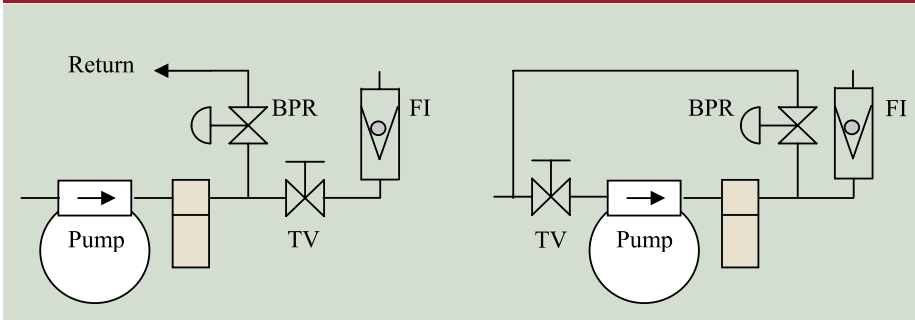
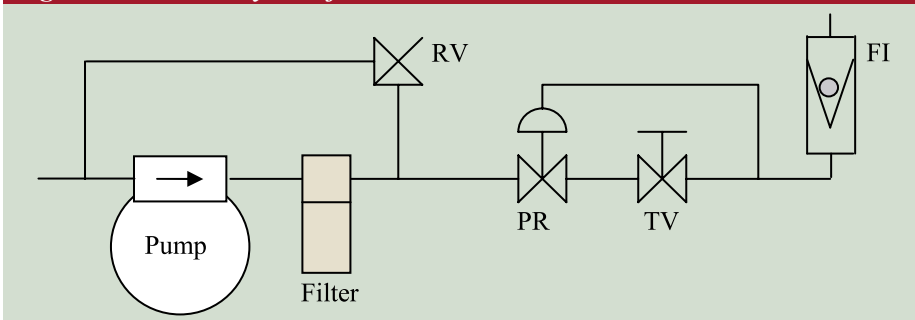


Figure 8: constant system flow rate



reduced as a result of the increased restriction introduced by the throttle valve, resulting in pressure reduction at the pump inlet. The gauge pressure at Pa will decrease to a vacuum with the TV closed.

Configuration B flow rate is again reduced as a result of the increased restriction by TV, but this has the effect of increasing pressure at the pump outlet – up to a maximum of the pump capacity. Depending on the pump characteristics, the pressure increase at Pb may range from 30 psig to 100 psig or more. Excessive outlet pressure on the pump diaphragm (configuration B) will result in increased diaphragm and bearing stress, reducing pump life and increasing service requirements. However, locating the valve before the pump inlet avoids the condition of high diaphragm pressure and is the recommended location of the throttle

Photo: F.L.Smith Minerals



valve.

• **Flow control with relief valve:**

Use of a relief valve (RV) reduces the high-pressure pulses on the pump diaphragm, as in the above case where a throttle valve is located at the pump

outlet (Figure 5). Flow pulses will therefore be reduced. The return line may be connected to the process or pump inlet, depending on which provides the lowest cost.

• **Constant outlet pressure:** A back-pressure regulator (BPR) will provide better pressure regulation than a relief valve. A BPR located before the analyser will provide the best pressure regulation (Figure 6a and b). Adding one or more filters is optional, but will give additional pulsation reduction and therefore also help system performance.

• **Constant system flow rate:** The use of a pilot-operated pressure-reducing regulator (PR) with a throttling valve configured as shown in Figure 7 provides a constant flow rate independent of the pressure upstream of the pump. Downstream pressure is assumed to be constant. This design may be used for systems that have constant time delay or constant response-time requirements.

System design

There are many aspects to consider when using a diaphragm pump in a sample system. The design of the system itself must meet the required response time. This is often dependent on sample line size and the placement of the pump.

There are many ways to control pressure and flow. Knowing when to apply these various techniques is an important aspect of designing a sampling system. Pump pulsations can have a negative effect on various instrument readings and should be considered at the beginning of the design process.

The above discussion only touches on a few basic methods and is by no means complete, but is intended to provide a starting point for system design using diaphragm pumps. There are many approaches to sampling system design; but, in general, simplicity is the key. <<

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