Closed Loop Grab Sampling

HANDBOOK

A reference for plant process and project engineers, maintenance and operations professionals.

SENSOR
SAMPLING SYSTEMS

Introduction

At the surface, grab sampling may appear simple. Just gather some process data like pressure, temperature, vapor pressure, viscosity, thermal conductivity … and voila! You've got the correct solution! But upon closer inspection you realize there are few subject matter experts on staff, few documented best practices, an underlying tendency to make things too complicated and just a general underestimation of what it takes to achieve success. A successful installation is one that operators can use and use as designed, produces reliable information and doesn't create problems or interfere with other operational programs such as LDAR (Leak Detection And Repair).

This handbook is intended to help you design a grab sampling station that will mitigate hazards to plant personnel while producing the most accurate results possible.

A number of factors that may lead to problems on sampling projects will be covered in this handbook so that you can learn without having to experience them directly. We'll start by stating the obvious – Grab Sampling as a discipline, is significantly less important to your facility's operation when compared with equipment such as control valves, compressors, pumps, control systems, or even transmitters. However, this doesn't mean that it's not important, because there are degrees of criticality in any facility. As such, in-house personnel with the experience and expertise are just not as readily available for this type of niche equipment.

This short handbook is intended to help you design a grab sampling station that will mitigate hazards to plant personnel while producing the most accurate results possible. It is concise and to the point, and will focus on the factors and constraints that are most critical to success.

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1 Why Take Grab Samples?

They probably didn't ask the above question in your college engineering classes. The short answer is that process operations require samples to help manage quality, yield and other important variables that are critical to your facility's production. In some hydrocarbon processing facilities, the process is actually licensed to the manufacturer from the original inventor of the process. In these cases, the sample points were laid out by that licensor. Your operations group may also have added to these locations over the years for critical areas during start up, or in locations where certain "cuts" are important. In recent years, these sample points have become more sophisticated due to the added risk of injury to operations personnel and environmental impact.

The short answer is that process operations require samples to help manage quality, yield and other important variables that are critical to your facility's production.

Sample Safety

Operators taking samples from a process that might be at high pressures or at high temperatures, or may contain gases Immediately Dangerous to Life and Health (IDLH), require specially designed valves and techniques in order to mitigate these hazards. This could involve wearing special Personal Protective Equipment (PPE) or breathing air or engineering the hazard away from the interaction. By implementing engineering controls we can make grab sampling safer for operations personnel. So let's focus on the equipment you need to sample hazardous chemicals or streams that contain hydrocarbons.

Capturing the Vent

For chemicals and hydrocarbons, the goal is to retrieve samples reliably with no environmental impact, so we need to have a strategy for capturing the vent. This simply means that when we take a sample, we want to capture and direct any potentially hazardous vapors away from personnel to an area where they can be diluted, destroyed or chemically neutralized. The two primary methods for capturing the vent are **(Figure 1)** a bottle, cap and septum system and, **(Figure 2)** an enclosure and Eductor system. Grabbing a sample in an open bottle and then applying a cap is not generally accepted as an approved strategy for capturing the vent by most hydrocarbon processing facilities.

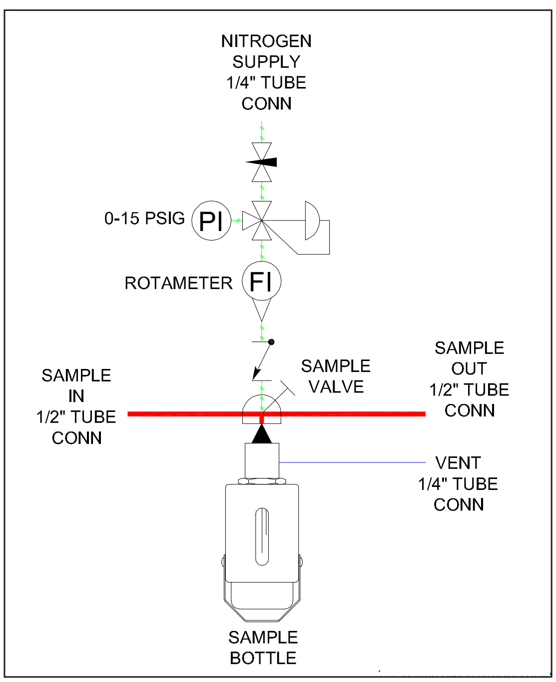

Figure 1 - Bottle, Cap & Septum System

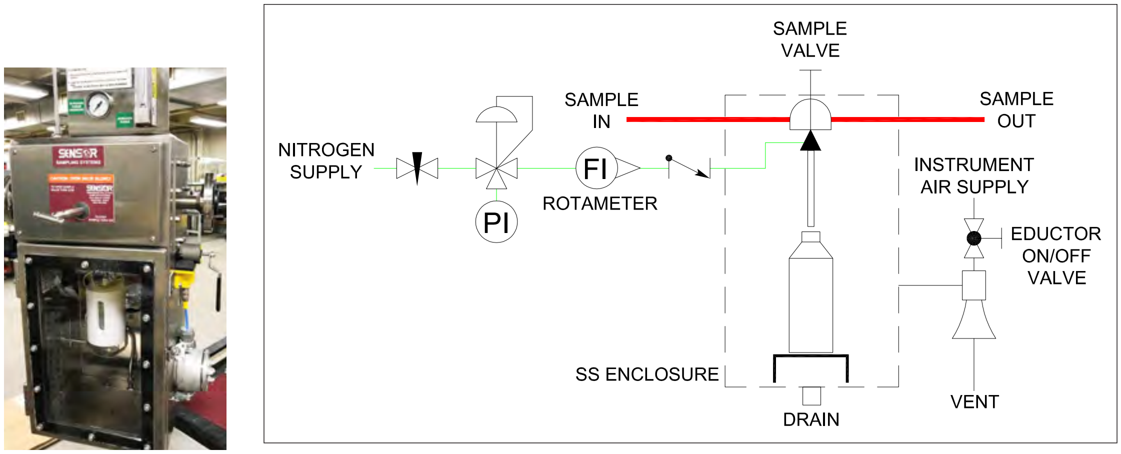

Figure 2 - Enclosure System for Inline Service

2 Identifying Your Sampling Points

Whether you're the newest engineer on staff or the most experienced among your peers, executing a grab sampling project is deceptively complicated and always frustrating.

Does your plant have standards for sampling different process streams?
Are there standards that can be referenced?
What did the plant do for the last sampling project?
Does operations have usable ideas?
Who are the "experts" in your facility?

These are all great questions, but the answers inside your facility are likely limited to a handful of opinions. The bottom line is that most facilities are lacking official documentation that could be useful to you on this particular type of project. There will be no shortage of opinions and ideas for how to improve sampling in your facility, but most of the time, this will not lead to a suitable result.

Your project might include 100 sample stations and you could be leading a small team of engineers, or you might be flying solo on small cap project where there are only 4 or 5 sample stations. Either way, you will want to complete the project under budget while meeting your goals and alleviating any hazards.

The good news about locating sample points in your facility is that, for the most part, it has already been done. Process engineers and lab personnel have identified key areas of the process where quality and yield need to be checked to ensure the process is operating correctly. In some cases, there are additional sample locations required to cross check online analytical instruments and process gas chromatographs.

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Utilizing a Fast Loop

The key factor is to identify a *fast loop*. A *fast loop* is simply a place in the process where we can extract the sample at high pressure and return it to the process at a lower pressure, thus creating a flow through your sample point. The importance is not how high or low the pressure is, but rather the differential in the bypass of the fast loop. In most applications, you should have at least 5 to 8 psig difference between the high pressure inlet and the low pressure outlet. Process physical properties, such as higher viscosity or a high concentration of solids may call for a higher pressure drop in the fast loop. So why design a fast loop? There are three primary reasons for designing a fast loop through your sample panel.

1. To ensure the sample being caught is representative of the process
2. To reduce plugging and improve the reliability of the sample station
3. To minimize dead volume which often leads to plugging and sample contamination

Illustrated below in **Figures 3** and **4**, are two common methods for achieving a fast loop.

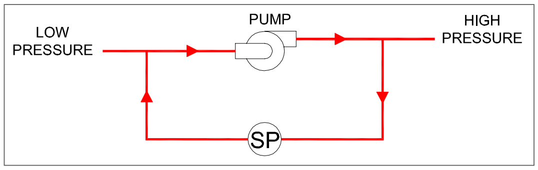


Figure 3 - Fast Loop using a Pump

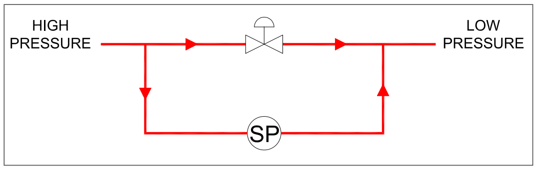


Figure 4 - Fast Loop using a Control Valve

Grabbing samples from a reactor or a tank with NO fast loop often leads to operational issues for the facility down the road. If it all possible, you should install your sample stations in a fast loop. The equipment will be more reliable, easier to maintain and draw fewer complaints from operations and the laboratory.

Minimizing Dead Volume

Sampling components, the sample loop, and your grab sample application, in general, are created with an eye on the potential for dead volume. It is one of three critical characteristics that lead to unsuccessful grab sampling installations. Dead Volume is a term used to describe the presence of process trapped in non-flowing locations in the sample loop. These locations can be found in poorly designed sample valves and other related components on the sample station, or in dead ended sample lines intended to flow toward a drain during sampling **(Figure 5)**. Sample valve technology and best practices are there to minimize the presence of dead volume. Station maintenance, reliability and availability are all negatively impacted when dead volume is not being considered in your grab sampling station design.

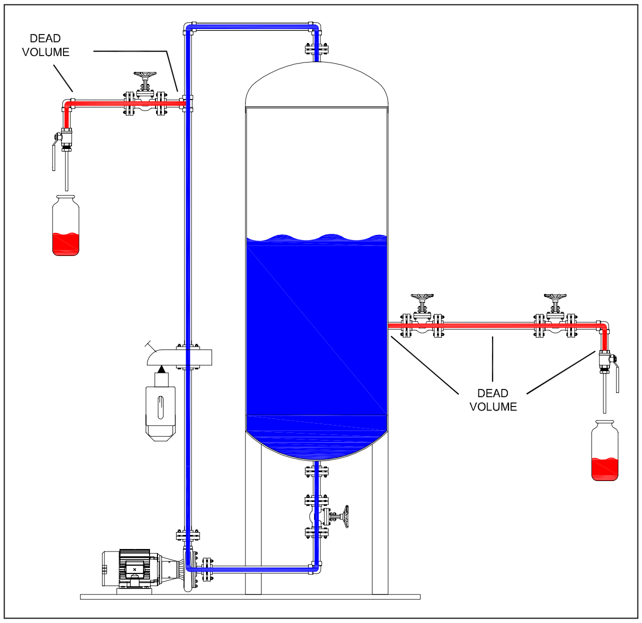


Figure 5 - Dead Volume

Finally, if the process you are sampling is viscous or requires heat in order to move through the fast loop, consider heat tracing the sample line. From time-to-time, operators can and do shut down the fast loop which increases the likelihood of plugging. Also, consider using pre-insulated tubing in lieu of "field trace and insulate" techniques. It is easier to install and provides superior thermal properties over mastic. When mastic gets wet, it can lose much of its thermal insulating capacity. Also, pre-insulated tubing provides better protection for personnel where the line approaches the grade.

3 Gathering Your Process Data

Gathering data is one of the most important and challenging aspects of a successful grab sampling project. In most refineries and chemical plants, the required data is scattered between the lab and operations, and each department could have conflicting information. If you are lucky enough to work in a plant that has a central repository for this information, you will be light years ahead of the game and can potentially avoid a huge headache! If not, you need to be organized and patient with your co-workers. In the end, they will likely help you get what you need.

The challenge for engineers is that different applications require different information. Many engineers are looking for a one-size-fits-all approach which will either not work or end up being cost-prohibitive. The key is to break the project into groups of applications and gather the required information for each group. Use the grouping listed below to categorize your applications. Within each grouping, you still may need additional sub-grouping depending on the process being sampled.

The challenge for engineers is that different applications require different information.

Application Groups

1. Low vapor pressure liquids (vapor pressure <19 psia) & process pressures <175 psig
2. Low vapor pressure liquids (vapor pressure <19 psia) & process pressures >175 psig
3. High vapor pressure liquids (vapor pressure >19 psia)
4. Gases / Vapors
5. Special hazards (e.g. process temperature >400°F)

Cooling Things Down

An additional category, common in grab sampling, where data will be required is in the use of coolers or heat exchangers. All chemical and hydrocarbon processing facilities will have a Health Safety & Environmental (HS&E) group that provides guidelines on the safe handling of sample containers. Usually, the sample temperature must be below 140°F to comply with HS&E rules for safe handling. This will be your target for cooling samples too hot to be handled by operations and lab personnel. To properly size heat exchangers and coolers for your sample streams, you will need to know the following.

Physical Properties	Process Media	Cooling Fluid
In/Out Temperatures (°F)		
In/Out Pressure		
Viscosity (cps)		
Specific Heat (BTU/(LB)(°F))		
Thermal Conductivity (BTU/(Hr)(ft)(°F))		
Specific Gravity		

The quality of your cooling water in the plant is another very important factor in the success of your cooler or heat exchanger application. Scaling and mineral deposits can have a detrimental impact on the overall performance of your grab sample station. Remember, if the cooler doesn't work, then the grab sample station cannot be utilized! Take the time to thoroughly investigate potential coolers and cooling techniques. Not paying close attention here can lead to unacceptable results for sampling and unsafe conditions for operations.

Note: See the tables in Appendix A, B and C for the required data for each group of sample station type and cooler for your project.

Required Data	Appendix
Groups 1, 2 & 5	A
Groups 3 & 4	B
Coolers & Heat Exchanges	C

Finally, most vendors will not specify metallurgy, valve packing and elastomers for your application, so it's important to know what is required in the process stream for which you are designing your application. As a starting point in metallurgy, if Swagelok, Hoke Gyrolok or Parker do not make instrument valves and fittings in the specific metallurgy you are seeking, then neither will your grab sampling vendor. Occasionally, the grab sampling vendor is asked to provide a solution in Chrome 9 or some other specialty material unique to piping systems. You simply will not find an engineered solution manufactured from this type of material.

Refer to Appendix D for a table showing standard metallurgy, elastomer and valve packing combinations and their typical limitations. It is important, however, to check your facility's requirements since process streams could contain trace contaminants that might dictate a completely different solution.

4 Challenges and Pitfalls

When you meet with your grab sampling consultant, you will want to discuss your plant's specific guidelines and practices for utilizing this equipment. Refineries and chemical plants have many specifications for piping, valves, utilities, flare systems, venting and other related topics. Your representative should be able to walk you through these areas just as an engineering consultant would walk you through the scope of a project.

The first area that you need to communicate is the "big picture". What specific challenges is your facility facing? Is it personnel exposure, environmental impact, equipment reliability or all of the above? It's important for you to explain your experience with previous technologies, good or bad. You want to be clear about each and every issue your operation is experiencing. No matter how insignificant it may seem to you or the team, there could be clues that will help your grab sampling consultant provide the best overall solution.

More Info, Better Outcome

Your grab sampling consultant will have specific questions about the stream data on the process that you would like to sample. It is important to cover the obvious information about the process stream itself, but there might be a need to discuss the purpose of the process, too. For example, let's say that you want to sample a caustic stream. This is a very simple application, but if the caustic stream is part of a scrubber process where gases such as, H_2S are being removed, you will need to tell your consultant. If not, your consultant is likely to supply viton on your sample station for the required elastomers, which is not compatible with H_2S. This oversight will lead to premature failure of the viton and severely impact the equipment's reliability.

In addition, if your old technology proved to be inadequate, it's important to cover all the factors surrounding this situation, so that your consultant can help solve your problem. For example, if you were utilizing a Piston Ram Valve to take your sample and your issues were related to chemical exposure as well as flow control to the sample container, your consultant will need that information.

Two Common Solutions

Grab sample stations for liquids, gases and high-vapor pressure liquids ALL REQUIRE VENTING before the sample container is removed from the station and transported to the lab. What is your facility's strategy to capture the vent during the sampling operation while protecting personnel and the environment? Usually this is well-defined on high vapor pressure liquids and gases but very often overlooked when it comes to low vapor pressure liquids. In Chapter 1 we introduced the most commonly used techniques for capturing the process vent for low vapor pressure liquids. Over the years, more sophisticated and elaborate methods for capturing the vent have been developed, but these methods lack simplicity and more importantly, a successful track record for availability and reliability of the final asset. Let's discuss two of the most common and reliable solutions.

Grab sample stations for liquids, gases and high-vapor pressure liquids ALL REQUIRE VENTING before the sample container is removed from the station and transported to the lab.

1. Process/Vent Needle Systems with a bottle, cap and septum are used for the vast majority of chemical and hydrocarbon processing streams. They offer a cost-effective method for safely and reliably retrieving samples in most chemical and refining operations. An illustration of the sample and vent modes for these systems is shown below in **Figure 6**. Notice that the process stream flows through the valve body unimpeded by the sampling operation.

While the valve is being OPENED, only a small portion of the fast loop leaves the process stream and flows into the bottle at line pressure, offering a high degree of flow control. Since line pressure is higher than the nitrogen pressure, the check valve on the purge system closes and allows only process to fill the bottle. The ball and seat of the valve is just millimeters from the process

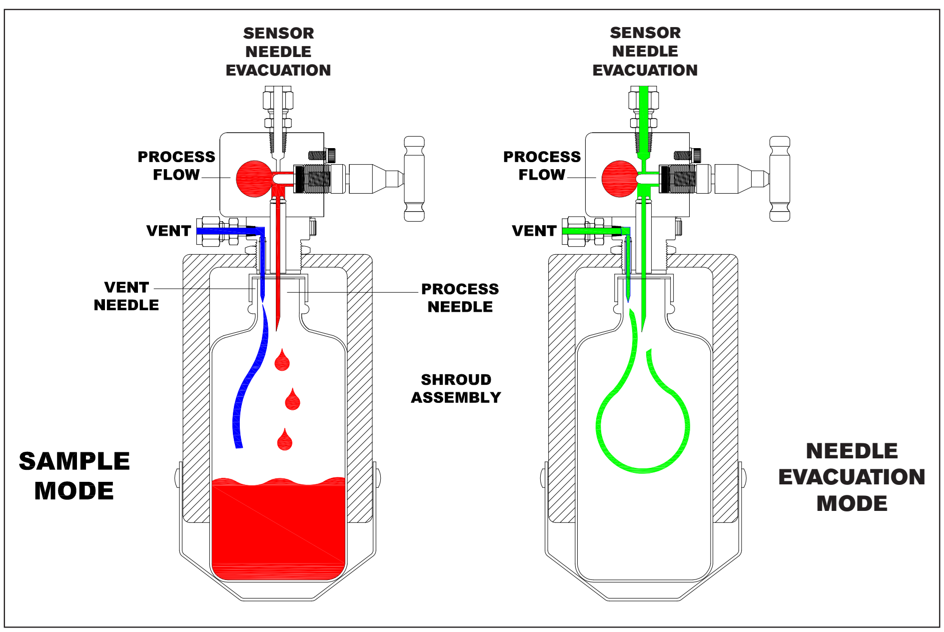


Figure 6 - Bottle, Cap & Septum System

fast loop, virtually eliminating dead volume while keeping the seat clean from debris. As soon as the valve is returned to the CLOSED position, isolating the valve body from line pressure, the nitrogen pressure opens the check valve and vapors are automatically swept through the sample path. This will clear any dead volume and sweep potentially hazardous vapors to an approved SAFE venting location.

2. Enclosure Systems with an *eductor* allow sampling from outside the enclosure. Hazardous vapors or smoke inside the enclosure during the filling operation can be removed by installing an educator, which routes them to a safe location away from plant personnel.

Connecting your vent system to a *safe location* depends on plant guidelines and local environmental standards. A simple carbon canister or other absorbent may work just fine. You may also be able to vent into the atmosphere if volumes are low and the gases diffuse rapidly. Check with your facility, the lab, the HS&E group or the Operations Manager to ensure you are within plant guidelines.

Make the Right Connection

The vent and how it is connected to your facility is a critical aspect of your project! Even though the sampling consultant provides the vent connection on the sample station, it's your job to connect it to your safe venting location. For low vapor pressure stations, the vent system must have little or no back pressure to overcome during the sampling process. Connecting the vent to your facility and plumbing it correctly are essential to the proper operation of grab sample stations. Make sure your grab sampling consultant is very clear on where you intend to tie-in the vent. You may need to utilize check valves and other components to properly control venting. A poorly installed or maintained vent connection will definitely lead to reliability problems and could lead to more serious problems involving personnel exposure.

Connecting the vent to your facility and plumbing it correctly are essential to the proper operation of grab sample stations.

The problems common in low vapor pressure liquid systems are not common in (high vapor pressure liquid[1]) or gas applications. High vapor pressure hydrocarbons tend to be clean, so they don't plug the vent or depressurization lines. However, you need to account for liquids or gases in the flare back-flowing from the header to the sample station. This issue can be resolved by locating a check valve at the sample station and another check valve at the flare header connection. Also, if the flare header line runs horizontally, you should make your connection at the topside of the flare header. These guidelines are simple but often not incorporated by the contractor installing the equipment. You will experience much better project results if you take the engineering time to create some detailed drawings for these various conditions. Your sampling consultant should be able to help you with these details.

[1] Common High Vapor Pressure Hydrocarbons

Methane	Ethane	Propane
ISO Butane	Butene	Pentene
Acetylene	Propyne	1-Butyne
Ethylene	Propylene	cis-2-Butene
1-Pentene	Proadiene	1,3-Butadiene

Sampling Technology

Your grab sample station should be designed with simplicity in mind. Deviating from a standard design increases the complexity of the operation and can cause operators to use the station improperly, or even not at all. It is important to utilize your consultant's technology and not try to "reinvent the wheel" for your project. You will be better served by focusing on the application details and making sure your consultant has the proper information to help you make an informed recommendation for your grab sampling application.

Sampling Made Simple

Many engineering and construction firms are skilled at designing piping systems, but are not experienced in the use of sampling technology. They often fail to consider such critical concepts as dead volume and venting, and will issue drawings that do little to utilize the technology. Once these drawings have been placed on paper, it becomes very difficult to re-direct the engineering group's efforts to change these details. The result is a system that is overly complex and fails to address the operational issues discussed earlier in this handbook. To avoid this outcome, you may have to take a more proactive approach with your engineering contractor in a large, integrated project.

When proper sample technology is not utilized, the system gets more complex and operators get more confused.

When proper sample technology is not utilized, the system gets more complex and operators get more confused. You can have the greatest sample station design ever created, but if Operations is not using the equipment as it was intended or not at all, you run the risks of operator exposure or environmental impact. Manufacturers who specialize in sample valve technology can simplify sampling procedures and minimize the complexity of the sample station making it safer to use. Standard instrument valve technology is not as effective in controlling the sample filling operation, eliminating dead volume and capturing the process vent. Homemade or overly complex systems are more likely to set off personal gas alarms and can sometimes prevent the equipment from passing LDAR inspections.

Over the years, project teams have wasted millions of dollars attempting to make grab sampling absolutely foolproof by needlessly increasing the complexity of their equipment. Albert Einstein once said, "Your hypothesis should be as simple as possible, but no simpler." Grab sampling follows a similar philosophy. The simplest approach offers the highest degree of safety and reliability.

Sample Container Fit

Low Vapor Pressure Applications

It is important that your new sampling equipment works well with your existing bottle supplier. Bottles used for low vapor pressure applications should fit snugly (but not tight) in the shroud so that the bottle and cap are aligned with the sample station and the needles properly pierce the septum when inserting the sample bottle. Without proper bottle fit, the needles might strike the cap instead of piercing the septum in the cap. This could bend one or both of the needles causing the system to work improperly, or not at all. Take the time to identify the correct bottle for each application and consider giving your sample station consultant a bottle that he can forward to the factory to ensure the best possible fit. If you have two different sample bottle size requirements on the same sample station, consider purchasing a shroud insert that allows you to sample using a smaller bottle in the existing sample station. This additional shroud is normally tethered to the station with a chain or cable to prevent it from being lost.

High Vapor Pressure Liquids and Gas Applications

Because high vapor pressure liquids and process gases are sampled at process pressure, a cylinder is used to maintain the quality of the sample. In conjunction with the cylinder, these systems utilize quick-connects and hoses to make attachment and detachment to the station quick and easy. These components are attached and reattached many times over the course of months and even years by operators, so the cylinder is designed to fit into a saddle system to assist in alignment and minimize wear and tear.

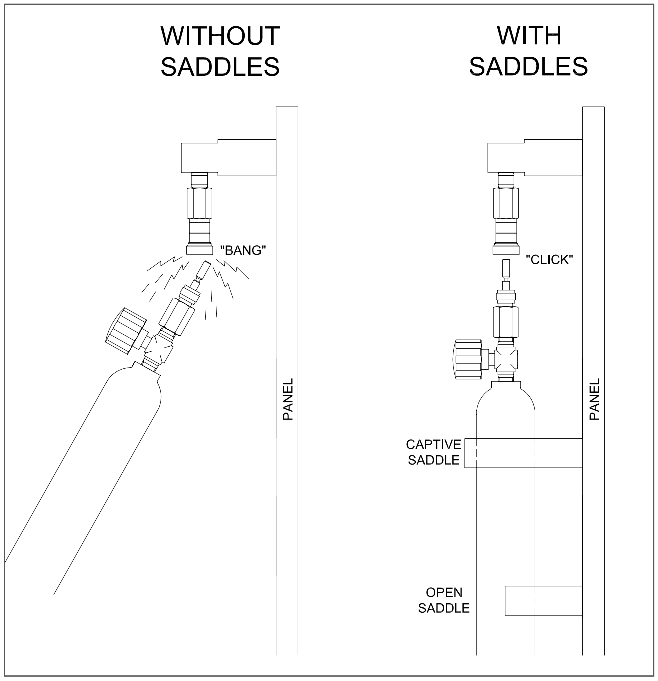


Figure 7 - Alignment - Cylinder Saddle System

The saddles are different sizes for different size cylinders. **(Figure 7)** Make sure you are clear on the size of cylinder you intend to use on the sample station. If your facility utilizes special labeling or sleeves for the cylinders, you might consider loaning a cylinder to your grab sampling consultant to ensure proper fit from the factory. If the saddles are not properly sized from the factory, operators will often alter the station or break the saddles so that the cylinder can be connected. This defeats the purpose of supplying the saddle system in the first place and will lead to premature failure of the quick connect components.

Another element of proper fit on a cylinder system for liquids is the alignment with the *sight flow indicator* with a minimum 20% *outage*. Because these liquids contain stored energy, we have to create an *outage* in the top of the cylinder for the liquid to expand into if the cylinder is subjected to heating. Otherwise it could rupture the cylinder potentially endangering plant personnel. Refer to **(Figure 11)** on page 15 for more detail on the 20% *outage* and the mounting position of the *sight flow indicator*.

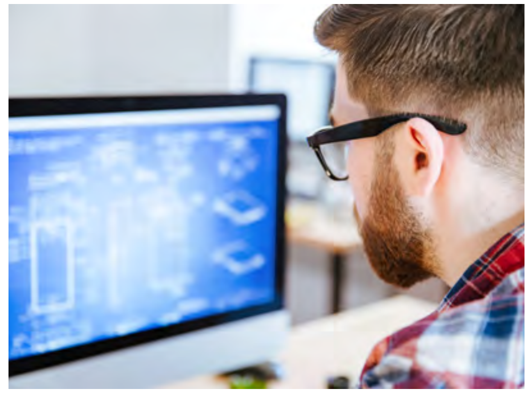
Project Schedule & Deliverables

Executing a sampling project is less complex than almost any other type of project, but that doesn't mean it's easy. Everything associated with these projects is very application specific and loaded with important details. For example, you might have what appears to be a simple project with five seemingly identical sample stations. On closer inspection, you notice that are three different pressure gauge ranges, two different elastomer types, two different valve packing types and three different sample bottle sizes. The next thing you know, something that seemed simple and straight forward is now more complex and loaded with details that cannot be ignored. Instead of having five identical items, you now have five unique line items on your purchase order. Staying organized can and does make all the difference.

Executing a sampling project is less complex than almost any other type of project, but that doesn't mean it's easy.

Drawing on Experience

All of these unique features should be detailed on the flow drawings for each application provided by your grab sample consultant. You should expect these drawings within a week or so along with a written quote for your application(s). For non-standard, more complex designs, the CAD work could take a week longer to produce. Keep this in mind when planning your project and the execution of the scope.



Flow drawings are an important tool to help you understand your consultant's recommendation and help your consultant communicate the scope of supply for the project's sample points. Your consultant should have a simple as-built or approval drawing process that can be executed within a time frame that works for your project schedule. Drawings can sometimes create a bottleneck in the delivery of your project.

Instructions and Sample Station Operation

Most grab sampling consultants will provide the recommended operating instructions on both the flow drawings as well as the actual sample station mounted in the field. It is very important that the operator follows the instructions to capture the sample safely with no environmental impact and without negatively impacting the reliability of the sample station.

The proper sequencing of the valves can be the difference between a very reliable sample station and one that is plugged and rendered useless. Let's assume you and your consultant decide to utilize a fixed volume technique for an application at 125°F and 1100 psig. A typical pressure isolating system **(Figure 8)** will trap the sample between two valves and blowdown the sample at a regulated nitrogen pressure set to 6 psig. In this case, with both valves normally closed, the correct instructions are as follows:

1. Open the Sample Valve and allow the collection chamber to be filled
2. Close the Sample Valve
3. Open the Secondary ISO Valve
4. Observe the Sample being dispensed into the bottle with low pressure Nitrogen
5. Close the Secondary ISO Valve after collection chamber has been dispensed
6. Remove Sample Bottle from the sample station

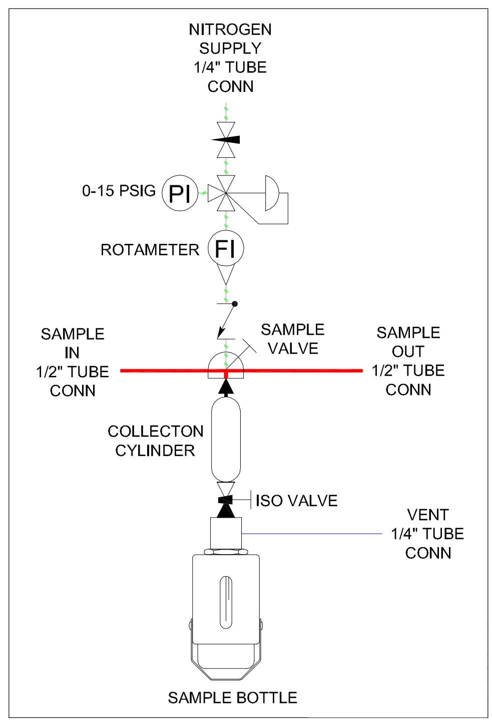


Figure 8 - Pressure Isolating Bottle, Cap & Septum System

In chemical and hydrocarbon processing, operations personnel are instructed to first open valves nearest the atmosphere, then additional valves upstream. As you can see from the instructions above, this would be exactly the wrong sequencing resulting in dead volume, sample contamination and eventual plugging of the sample station itself.

5 Mitigating Application Hazards

In section 3, "Gathering Your Process Data", we introduced the idea of breaking the sampling applications into groups. In section 5, we will look at these groups in greater detail to give you a better understanding of why one sample station design should be selected over another. The reason behind the suggestion for grouping the sampling applications is that these groups of sample points utilize different techniques for mitigating a particular hazard such as high temperature, high pressure, dangerous gases, etc.

Five Application Groups

GROUP 1 - Low Vapor Pressure Liquids (<19 psia, Line Pressure <175 psig)

This group of sampling stations is simple and straight forward utilizing a manual *flow-thru sample valve* and *needle system* in conjunction with a bottle, cap and septa for capturing the vent. **(Figure 9)** It is suitable for processes that cover a wide range of liquids where process pressure and temperatures are less than 175 psig and 350°F respectively. For more viscous liquids and instances where it is likely for liquids to stay trapped in the process needle, you can add a nitrogen purge system to eliminate the straw effect. A nitrogen purge system is also useful for sweeping vapors through the vent connection, away from the operator and sample station. The nitrogen system is typically set to operate between 3-5 psig.

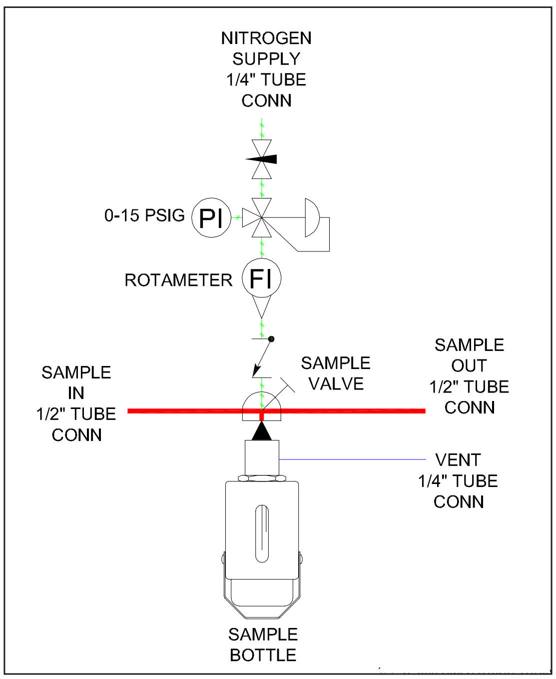


Figure 9 - Bottle, Cap & Septum System

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GROUP 2 - Low Vapor Pressure Liquids (<19 psia, Line Pressure >175 psig)

This group of sampling stations differs from the previous with respect to process pressure. When process pressures are above 175 psig the potential danger can increase substantially, especially if there are hazardous vapors present. **(Figure 10)** The actual volume of vapors increases dramatically when the sample valve is opened to the atmosphere, compounding any potential hazard that may exist. For these applications, your grab sampling consultant will usually propose a pressure isolating system, which traps the sample in a vessel and then is blown down into the sample container at the nitrogen purge pressure.

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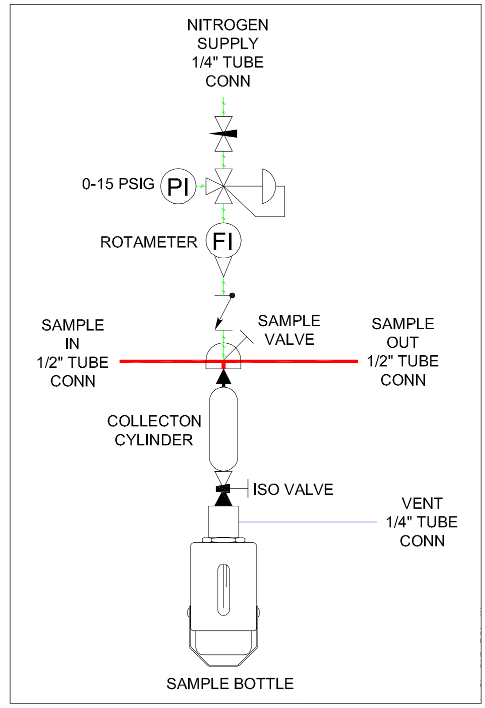

Figure 10 - Pressure Isolating Bottle, Cap & Septum System

GROUP 3 - High Vapor Pressure Liquids (>19 psia)

High vapor pressure liquids are typically caught in cylinders to contain the sample at the same process conditions for lab analysis. To get the proper, safe *outage*, the system is vented or depressurized to create a 20% head space in the top of the cylinder so that liquid exposed to heating can expand into this space. The vent for vaporizing this excess liquid is almost always connected to a flare header or vapor recovery system. The volume of material vaporized during this step in liquid systems is substantial and does not lend itself to using carbon canisters or other absorption techniques. Standard cylinder sample stations **(Figure 11)** are good for applications with pressures up to 1400 psig and about 180°F.

LGSS

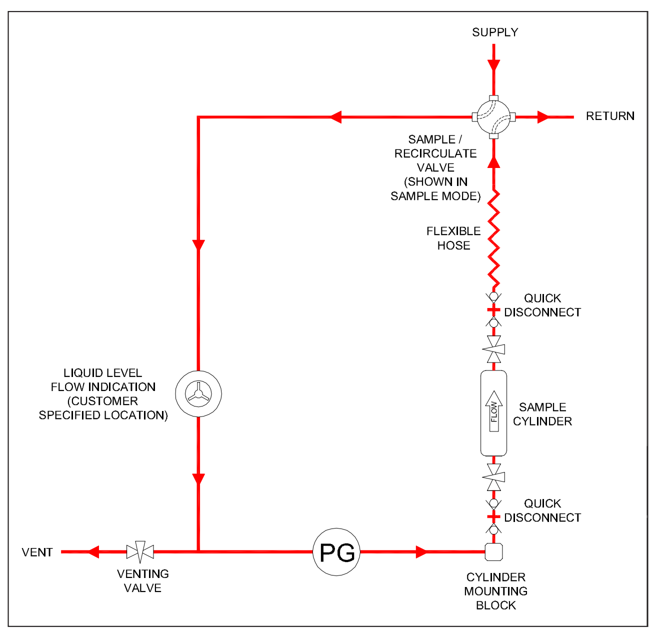

Figure 11 - High Vapor Pressure Liquid Cylinder System

To achieve the *outage*, best practices tend toward a visual verification during the sampling operation. Therefore, high vapor pressure liquid sample stations utilize a sight flow indicator aligned with the cylinder at the 80% full line. The operator can visually verify that the cylinder is only 80% full. In the event that the cylinder comes into proximity with a radiant or inductive heat source, the liquid is allowed to expand into the head space of the cylinder.

Some customers will use a *dip tube* to achieve a 20% *outage* in their sample cylinder. This is an effective method and is less expensive to implement, but may not prove to be as reliable as the newer, visually verifiable technique using the *sight flow indicator*. Because this potential hazard can be so dangerous to personnel, it's important to note why you should consider the *sight flow indicator* as an alternative, or use it in conjunction with the *dip tube*.

Dip Tube: Theory vs. Reality

In a liquid sample station the cylinder fills from the bottom and the *dip tube* is mounted inside and at the top of the cylinder. The liquid level rises uniformly toward the *dip tube* during filling and ceases to continue higher once the rising liquid has met the bottom of the *dip tube*. The flow is allowed to continue through the station without filling the cylinder further. The cylinder cannot be filled past the height of the end of the *dip tube* because the pressure inside the *dip tube* is lower than the pressure in the head space of the cylinder. However, high vapor pressure liquid is very turbulent and the liquid level doesn't necessarily rise with a nice flat surface. Thus, the potential exists for overfilling the cylinder and not achieving the desired *outage* for SAFE transport of the cylinder to the lab. **(Figure 12)**

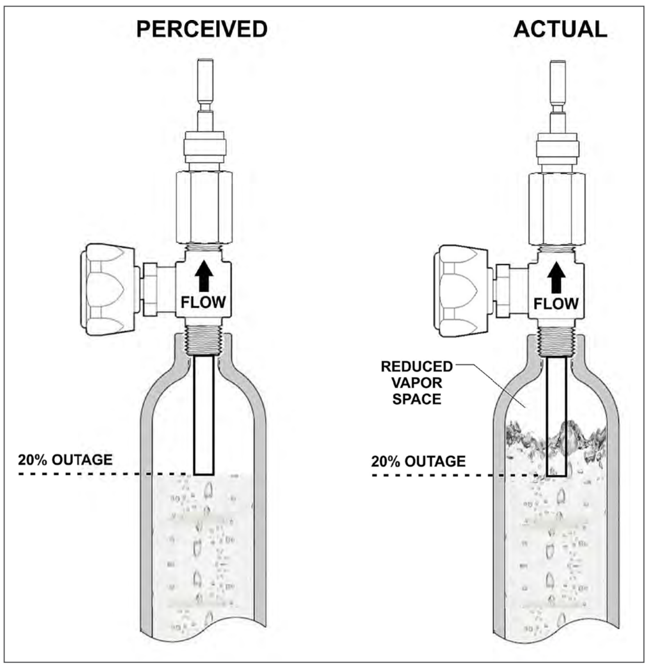

Figure 12 - High Vapor Pressure Filling with a Dip Tube

A popular backup technique for mitigating a potential rupture of a sample cylinder filled with high vapor pressure liquid is the use of pressure relief valves (or PRVs) or rupture discs. These devices are designed to contain pressure to a specified level and once the level has been met, the high pressure is vented into the atmosphere. These are last-line methods and don't address the underlying cause of the hazard, but are effective safety measures for protecting personnel.

GROUP 4 - Gas and Vapors

Unlike liquids, gases are compressible and easy to capture in a cylinder without concern for an *outage*. The high vapor pressure liquid systems are very similar to gas or vapor systems with the exception of the *sight flow indicator* and the direction of flow **(Figure 13)**. Liquid systems flow from the bottom of the cylinder to the top, while gas systems flow in the opposite direction to allow the liquids to be swept from the cylinder.

VSS

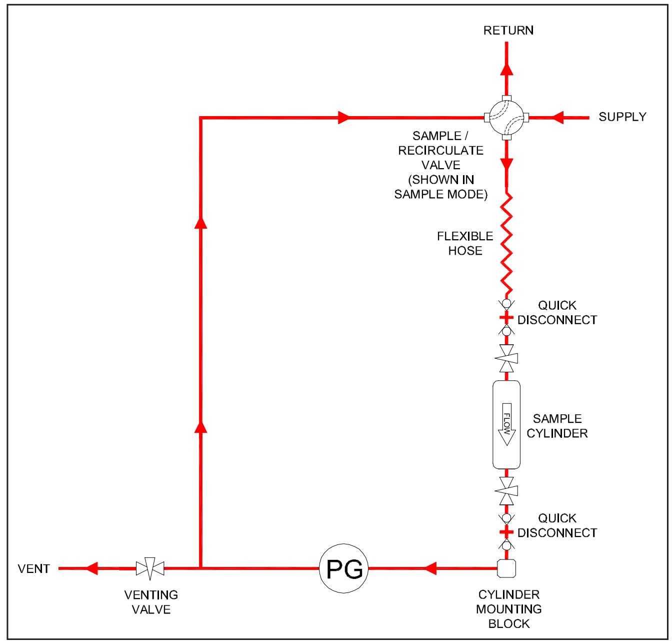

Figure 13 - Gas or Vapor Cylinder System

These cylinder sample stations utilize quick-connects that are spring-loaded and have a built-in check system for safety. There are also a number of o-rings inside each quick connect that must be compatible with the process. For example, H_2S is not compatible with the standard o-ring (Viton®) and you should consider Kalrez® or some other material compatible with H_2S in this instance. Also, in colder climates, depending on the process temperature, it might be necessary to consider installing the station inside a heated enclosure. O-rings from different materials have different *durometer* values which can impact the performance of the quick-connects in colder climates. *Durometer* is a physical property in elastomers that measures the ability of the material to return to its form after having applied a force to it. When an elastomer utilized inside the quick-connect has a low durometer value, the quick-connect may not perform as intended and could leak or not seal/check properly.

GROUP 5 - Special Hazards

Many facilities have special hazards that require techniques not previously mentioned. These hazards might include very high temperatures, high viscosity or lethal service just to name a few. The same principles apply to these applications that are present in the more common services. You want to minimize *dead volume* by utilizing a *fast loop*, select the correct materials of construction, keep the design simple and utilize the technology offered by your sampling consultant. In the case of lethal service, all-welded construction, face seal fittings and the use of an enclosure are all common features to eliminate leak points and minimize exposure.

It's a Dirty Job

Resid is a common special hazard grab sample application in most refineries. This application requires that Operations retrieve a sample from a stream whose temperature can be as high as 700°F and cannot be cooled using conventional coolers, because at ambient conditions the process is a solid. Sampling *resid* in a refinery is one of the most hazardous and dirty grab samples one will ever have to take, but the technique is simple and straight forward. The station is mounted in a piping *fast loop* and completely shrouded in an enclosure with a door and a window. The sample is caught in a can with the door closed and allowed to cool inside the enclosure for a period of time. Because the sample is hot and often smoky, an *educator* pulls a slight vacuum on the enclosure to *capture the vent*. The entire process flow path is insulated and heated. In this case, the technology is being utilized and only the procedure is being modified. To over-complicate such an application would compromise reliability, availability and safety.

Sampling resid in a refinery is one of the most hazardous and dirty grab samples one will ever have to take, but the technique is simple and straight forward.

Not a Simple Sample

Refineries with hydrofluoric (HF) alkylation units as part of their process must also utilize very specialized designs and techniques for sampling this stream. HF Acid is an extremely corrosive fluid and can cause death with even the slightest level of exposure. Without an effective design for sampling this process, personnel are left with only one option for mitigating this particular hazard, a full chemical suit and respirator. These systems are much more expensive than the standard designs discussed previously due to the exotic metallurgy required and the specially designed valves and sample container components.

Closed loop sample systems for HF Acid sampling consist of two separate stations; 1) a sample station mounted in the field and connected to the process so that operators can safely grab samples from the HF process, and 2) a desktop mounted fixture for the lab so that the sample can be accessed from the special sample cylinder and safely extracted for analysis. These systems are usually fabricated from either Monel or Hastelloy depending on the specific requirements of the facility.

Not all manufacturers of closed loop grab sampling systems have experience with this specific application. It is important to make sure you have the right partner when working on a project of this type. Overly complicating the design in an effort to make it safe by using standard instrument valves, can actually increase the risk associated with grabbing this sample from the process.

Specialty Applications

Finally, there are applications for sampling that help you comply with local water regulations or provide high value measurement or analytical solution. Two of the more common applications that fit these characteristics are:

Sampling water discharge from a facility to a public waterway using a composite sampler.

This system is designed to take and move small periodic samples into a larger container which can hold dozens or hundreds of individual samples. This PLC-based system utilizes either a timer or an input from a flow meter to initiate the sampling operation. The single container is retrieved at the end of the shift or day and analyzed in the lab for the presence hydrocarbons and specifically VOCs. Depending on the potential VOCs that could be present, the composite sample container may have to be refrigerated to keep the VOCs from vaporizing. Talk to your grab sampling consultant for more details on this application.

Gasoline blending and sampling.

Refineries have a number of gasoline blends that are manufactured at a single facility that must be checked for quality and accuracy to specification. Octane content and other additives are expensive and limited to only what is needed to meet quality requirements. These blending and sampling systems are used to monitor and control the quality of the finished gasoline to meet customer requirements. They are very complex relative to the sample stations described in previous sections of this handbook. Talk to your sampling consultant to see how they can help you manage your quality requirements for this particular type of application.

6 Reliability, Availability and Maintenance

A sample station is an asset, and like other assets such as valves, pumps and analyzers, its reliability and availability can be critical to a safe, profitable operation. Many factors come together to produce the optimal level of asset performance including; equipment design, application engineering and maintenance. Most chemical and hydrocarbon processing facilities have a working maintenance program that centers around specific trade skills and a work order management system to schedule, prioritize and track maintenance activity. Often equipment design and application engineering are overlooked as critical factors to overall asset performance.

There are three main areas that you can focus on during the implementation phase of your grab sampling project that will improve reliability, availability and overall asset performance.

Three Areas of Focus During Implementation

There are three main areas on which you can focus during the implementation phase of your grab sampling project that will improve reliability, availability and overall asset performance. These areas include;

1. sample valve design
2. dead volume
3. bottle, cap and septum selection

We have already discussed sample valve technology and dead volume in earlier chapters of this handbook. If you ignore the finer details around bottles, caps and septa, you might run the risk of reducing the overall reliability of your grab sample station.

Bottles, caps and septa are critical components in the sampling system, but are often mistakenly treated as commodities by purchasing. Most of the suppliers of these items are involved in providing equipment and single use items that you might find in laboratories of companies for industries such as, pharmaceutical, biotech and medical. Because the laboratory supply market is much larger than the chemical and hydrocarbon sampling market, there are fewer choices when it comes to septum thickness, material and cap customization. Laboratory personnel tend to use very small, single needles that do almost no damage to the septa. Refinery and chemical plant applications require larger, dual needles to handle higher viscosity, solids, pipe scale and other impurities that might be present within the processing facility. Because larger or dual needle requirements generally do more damage to the septum when pierced, you want to make sure that you use a septum with more thickness, that can take more mechanical abuse.

Also, the hole size in laboratory caps is quite small and can sometimes affect the reliability of the sampling system by damaging one or both of the needles. Because the needles work in conjunction with the bottle, cap and septum to capture the vent, it is important to make sure that these components will work together before turning over the sampling system to operations for regular use. It is always a good idea to work with your sampling consultant and your lab personnel to come up with the best overall solution for your facility.

7 Conclusion

Now that you've digested everything there is to know about grab sampling, or at least the most important points, it's time to get to work. But before you start, please remember that there are many stakeholders involved in and around the grab sample station. You do not want to make the mistake of being the "Lone Ranger" on your project, or you will likely just give up in exhaustion. You are the leader of your project but you will need help from your lab, operations personnel, your HS&E team, your sampling consultant, and others. It's easy for egos and attitudes to get involved which can derail your success early in the game. Be proactive and inclusive and you will likely sail right through without much conflict at all!

*You are the leader of your project but you will need help from your lab, operations personnel, your HS&E team, **your sampling consultant**, and others.*

In many ways, your grab sampling project can be a great way to get noticed and appreciated in your facility, even if you are a newer engineer with very little project experience. Be organized and ask your grab sampling consultant to help you, so that you will shine in the presence of your supervisor and peers. Also, take advantage of the technology and techniques that your grab sampling consultant has to offer. Your consultant has likely been exposed to many applications just like yours and knows how the equipment performs under similar conditions.

We wish you the best of luck with your project!

Glossary of Terms

Capturing the Vent – A methodology for mitigating vapor hazards and redirecting those vapors to a safe location, away from personal and environmental impact.

Composite Sample Station – A sample station design that takes multiple samples and deposits them into a common sample container, normally for the purpose of determining whether or not there are impurities in a water outfall to a public waterway.

Dead Volume – The presence of process trapped in non-flowing locations in the sample loop. These locations can be found in poorly designed sample valves and other related components on the sample station or in dead-ended sample lines intended to flow toward a drain during sampling.

Durometer – A physical property of elastomers that describes the ability of the material to return to its shape once force has been applied to it.

Engineering Controls – Method for mitigating hazard by engineering the hazard out of the design.

Fast Loop – A sample stream which is leaving the process at a higher pressure and returning to the process at a lower pressure, which allows flow through the grab sample station.

Flow-Thru Sample Valve – A specially designed valve to accommodate a *fast loop* and to sample the process stream without restricting or redirecting the *fast loop*.

High Vapor Pressure Liquid – For sampling, a liquid with a vapor pressure of $>$ 19 psia.

HS&E – Acronym for Health Safety and Environmental. This group develops and implements programs that are designed to keep personnel safe and the environment free from negative impacts that could result from operating a chemical or hydrocarbon processing facility.

IDLH– Acronym for Immediately Dangerous to Life and Health. Used when designating hazardous gases or compounds.

LDAR – Acronym for Leak Detection And Repair. This program is managed by plant personnel to make sure that there is a system in place to deal with fugitive emissions from certain classes of equipment.

Low Vapor Pressure Liquid – For sampling, a liquid with a vapor pressure of $<$ 19 psia.

Resid – Abbreviation for Residuum, which is a tar-like substance found in the Coker Area of a refinery. It is normally very hot, sticky and messy and one of the most difficult substances to sample in hydrocarbon processes.

Safe Location – A unique place to direct hazardous vapors as determined by plant guidelines and environmental standards.

Sight Flow Indicator – A device that allows an operator to view the actual process flowing through a line. It has a paddle wheel that also shows flowing material.

Appendix A

Sample Station Groups 1, 2 & 5
Low Vapor Pressure - Bottle Systems

SENSOR SAMPLING SYSTEMS

Bottle System
Application Data Sheet

Date	
Name	Phone
Company	Email

GENERAL

Media	Tag Numbers
*Pressure Inlet	Pressures over 150 PSI, Fixed Volume System is recommended
*Fast Loop Outlet Pressure	
*Vapor Pressure	Vapor Pressures > 19 psiA recommended sampled in Sample Cylinder
*Viscosity	(CP) at Sampling Temperature
*Temperature	For temperatures over 135°F, Process Cooling is recommended
Particles in Sample ❍ Yes ❍ No	Micron Size ____/____ (%) if >100 micron y-strainer recommended

MATERIALS

*Wetted Parts	❍ 316SS (std.)	❍ Monel 400	❍ Hastelloy C276	❍ Other________ *specify
*O-Ring Material (Elastomer)		❍ Viton (std.)	❍ Kalrez	❍ Other________ *specify
*Valve Packing Material		❍ Teflon (std.)	❍ Graphoil (Hi. Temp)	

CONNECTION AND MOUNTING

*Sample Inlet/Outlet Connection Size (1/4" Tube Standard)

*Sample Inlet/Outlet Connection Type (specify tube, NPT, Flange)

*Flare Vent Pressure______ Vent to Flare______ Vent to Carbon Absorber______ Tell Tale Crystals______

CONTAINER

Size				
*Material	❍ Glass	❍ Plastic	❍ Safety Coated Glass	❍ Other________ *specify
*Sampling Method	❍ Septum Bottle (closed loop, captured vent)			❍ Open Top Bottle
*Type	❍ Boston Round		❍ Customer (provide sample for manufacturing)	

OPTIONS

- ❍ PipeStand for Mounting System
- ❍ Needle Evacuation System (NES)
- ❍ Secondary Sample Isolation Valve
- ❍ Sample Cooler Heat transfer document needed.
- ❍ Enclosure Type Insulated ❍ Yes ❍ No
  Heated ❍ Yes ❍ No if yes, ❍ Steam or ❍ Electric if electric, Volts
- ❍ Process Block Valve ❍ Sample Inlet ❍ Sample Outlet ❍ Both
- ❍ Check Valve on Vent
- ❍ Non-standard Process Needle (.083std) ❍ .109 ❍ .148 ❍ 1/4" Stinger
- ❍ Steam Stinger
- ❍ Collection Vessel Size ❍ oz. ❍ mL (if applicable)

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Use page two for any comments/include sketch if available.

*Required information

Sample Station Groups 3 & 4
High Vapor Pressure Liquids and Gas - Cylinder Systems

SENSOR SAMPLING SYSTEMS

Cylinder System Application Data Sheet

Date	
Name	Phone
Company	Email

GENERAL

Media ❍ Gas ❍ Liquid	Vapor Pressure (at sampling temp)
Tag Numbers	
*Pressure Inlet	
*Fast Loop Outlet Pressure	❍ With Process Return ❍ Without Process Return
*Viscosity	(CP) at Sampling Temperature
*Temperature	Temperatures over 135 ° F, Process Cooling is recommended
Particles in Sample ❍ Yes ❍ No	Micron Size ____/____ (%) if >100 micron y-strainer recommended

MATERIALS

*Wetted Parts	❍ 316SS (std.) ❍ Monel 400 ❍ Hastelloy C276 ❍ Other________ *specify
*O-Ring Material (Elastomer)	❍ Viton (std.) ❍ Kalrez (recommended in H2S service) ❍ Other________ *specify
*Valve Packing Material	❍ Teflon (std.) ❍ Graphoil (Hi. Temp)

CONNECTION AND MOUNTING

*Sample Inlet/Outlet Connection Size (1/4” Tube Standard)	
*Sample Inlet/Outlet Connection Type (specify Tube, NPT, Flange)	
*Flare Vent Pressure	Type ❍ Flare ❍ Carbon Canister ❍ Other________ *specify

CONTAINER

*Size Sample Container	❍ 300cc ❍ 500cc ❍ Other________ *specify
*Cylinder Quick Connect Part Number Brand/PN#	
*Cylinder Accessories	❍ Dip Tube ❍ Rupture Disc ❍ Spring Relief
*Cylinder	❍ Supplied ❍ Customer supplied

OPTIONS

- ❍ PipeStand for Mounting System
- ❍ System Purge
- ❍ Sample Cooler   Heat transfer document needed.
- ❍ Enclosure Type   Insulated ❍ Yes ❍ No
  Heated ❍ Yes ❍ No   if yes, ❍ Steam or ❍ Electric   if electric, Volts ________
- ❍ Process Block Valve   ❍ Sample Inlet ❍ Sample Outlet ❍ Both
- ❍ Check Valve on Vent

Special Configurations available (contact your local representative for information): Detector Tube System, Lab Docking Station, Special Coatings (Siliconert)

Use page two for any comments/include sketch if available.
*Required information

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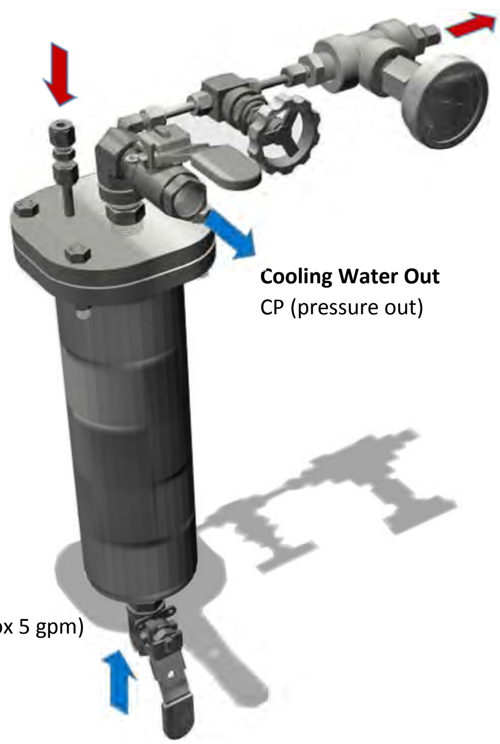
Coolers and Heat Exchangers
Bottle and Cylinder Systems

SENSOR SAMPLING SYSTEMS

Sample Cooler Specifications Data Sheet

Please fill out as many of the specifications as possible.

Customer			
Sample Point Sample		Media	
PROCESS PROPERTIES			
INLET		**OUTLET**	
(t) Temperature In (F)		(T) Temperature Out (F)	Approx 130°F
(p) Pressure In (psig)			
(v) Viscosity (cp)		(V) Viscosity A Outlet (cp)	
(h) Specific Heat (BTU/lb. F)		(H) Specific Heat (BTU/lb. F)	
(c) Thermal Conductivity (BTU/ft. F)		(C) Thermal Conductivity (BTU/ft. F)	
(g) Specific Gravity			
COOLING WATER PROPERTIES			
INLET		**OUTLET**	
(ct) Temperature In (F)			
(cp) Pressure IN (psig)		(CP) Pressure Out (psig)	



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Appendix D

Metallurgy, Valve Packing and Elastomers

Metallurgy	Standard (Yes/No)	Description
316 Stainless Steel	Yes	Good corrosion resistance for a variety of chemicals and hydrocarbons.
Monel®	No	Good corrosion resistance to harsher chemicals such as chlorine, ethylene dichloride and other materials that cause stress corrosion cracking.
Hastelloy®	No	Good corrosion resistance in specialty chemicals, acids, and other highly reactive products.

Valve Packing	Standard (Yes/No)	Description
Teflon®	Yes	Good for most applications with temperatures < 350ºF
Graphoil	No	Good for applications >350ºF and <550ºF where temperatures are too high for Teflon®.
PEEK	No	Good for aggressive specialty chemicals. Resists cold flowing at elevated temperatures.

Elastomers	Standard (Yes/No)	Description
Viton®	Yes	Good performance with most chemicals, hydrocarbons and petrochemicals.
Kalrez®	No	Used for limited applications where Viton® is not compatible with the process, e.g. H_2S.
Buna	No	Good general properties but not typically as good as Viton® and there is no substantial cost savings.

Kalrez® and Viton® are registered trademarks of E.I. DuPont de Nemours and Company
Monel® is a registered trademark of Special Metals Corporation
Hastelloy® is a registered trademark of Haynes Stellite Company
Teflon® is a registered trademark of The Chemours

About the Authors

Seth Martin has provided hundreds of companies with safe and reliable sampling solutions for a variety of applications and is considered one of the few experts in the field of grab sampling within the refining, chemical and petrochemical industries. He is currently President of Tech-SORce, an industrial manufacturer's representative organization in Texas Gulf Coast and a sales representative for SENSOR Sampling Systems who is owned and operated by SOR, Controls Group, Ltd., Lenexa, KS.

Billy Terry is a Product Manager for SOR Controls Group (SCG) team and is responsible for the overall product line management for SENSOR Sampling Systems. He has more than 25 years of experience working in various capacities focused primarily on sampling system product portfolios. Over the years Billy has held many roles, including Field Service Technician, Shop Supervisor, Head Quality Inspector, ISO9001:2008 Quality Administrator, Application Engineer and most recently Lead Sampling Engineer.

Padraic O'Neil is an Operations Specialist with over 20 years of experience in the design and manufacture of grab sampling systems. As an Operations Specialist, Padraic is responsible for the success of the project from start to finish, including initial CAD drawings, panel/enclosure design, ordering accurate and correct components, assembly, tubing, labels, testing, final documentation and delivery of the finished product to the facility.

About SENSOR Sampling Systems

SENSOR Sampling Systems, formed from the core SOR Controls Group competencies, is a manufacturer of closed loop sampling systems. These products leverage the reputation of SOR as a source for high quality products used to ensure process safety.

SENSOR sampling systems are designed to meet Leak Detection Repair (LDAR), Maximum Achievable Control Standards (MACT) and Volatile Organic Compounds (VOC) emission standards. EPA Regulations mandate the use of environmentally safe, closed loop and closed vent sampling systems. Our systems meet these strict EPA requirements while providing a safe, reliable method for collecting representative samples in a manner which minimizes exposure to the operator and the environment. SENSOR SAMPLING is dedicated to providing a simple way to collect a repetitive, quality sample, reduce emissions and create safe conditions in which to work. We offer many different types of systems specifically designed to meet your exact requirements.

SENSOR SAMPLING SYSTEMS

SOR Controls Group, Ltd. (SCG) is a global leader in the design and manufacture of measurement and control devices under the brands of SOR Inc., Smart Sensors Incorporated (SSi), SETEX Products and SENSOR Sampling Systems and Data Monitoring Systems. SOR Controls Group actively serves all sectors of the process industry with particular strengths in the oil & gas, petrochemical, chemical and power segments. SCG supports a network of sales and service personnel capable of addressing customer requirements in any geographic market around the world.

Sampling Systems at **SENSOReng.com**

BBSS
Basic Bottle Sampling System

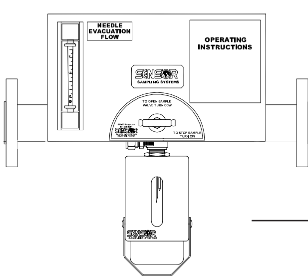
- Simple, flow-thru valve design
- Zero dead volume
- Replaceable process and vent needles
- Available with SENSOR Needle Evacuation System (NES)

LGSS & VSS
Liquefied & Vapor Gas Sampling Systems

- Safe, simple methodology for sampling high pressure liquefied gases and process gases
- Single handle operation
- Panel mounted pressure gauge
- Sight glass ensures safe cylinder outage on LGSS
- Ability to depressurize quick connects before removing cylinder

PIBSS
Pressure Isolating Bottle Sampling System

- Guarantees repeatable sample volume
- Zero dead volume
- Replaceable process and vent needles
- Suitable for high process pressures
- SENSOR Needle Evacuation System (NES) standard

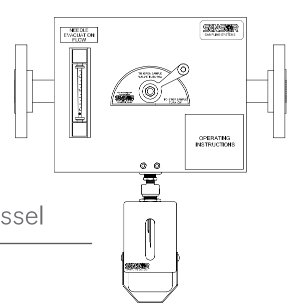


ISS
Inline Sampling System

- Available in wide variety of piping materials and end connections
- Suitable for high temperature, high viscosity service
- Available with open tube "stinger" or process needle

RSS
RAM Sampling System

- Available in wide variety of piping materials and end connections
- Suitable for high temperature, high viscosity service
- Available with open tube "stinger" or process needle
- Can be provided with a variety of connections to mate up to existing piping or vessel



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