Facility Purging with Nitrogen

STEP Engineered Nitrogen Services

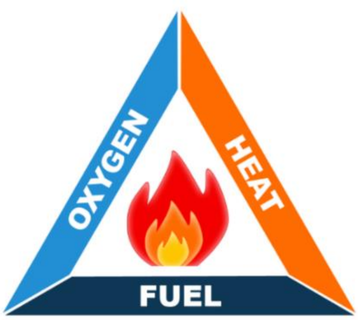
The safe purging of gas processing facilities, out of service and back to service, requires thorough consideration of key variables. Attention must be given to worker safety, the type and characteristics of hydrocarbon residing in the facility, process configuration and venting, metallurgical and materials limits. STEP Energy Services (STEP) was recently engaged to provide critical path nitrogen service to purge a facility out of service rendering it LEL-free (Lower Explosion Limit) for maintenance, and then making the system oxygen-free prior to gas feed-in. STEP was chosen for this large-scale outage because of its safety record, industry reputation in large scale nitrogen project execution, and engineering best practices related to the application of nitrogen within process facilities.

Discussion

During a facility purge it is necessary to employ proper processes to:

- prevent fire and explosions;
- ensure safety during maintenance works; and,
- control reactions and moisture in sensitive systems.

These goals cannot always be achieved through technology and equipment design alone; engineers may also rely on inert gases. Nitrogen inerting is performed to reduce levels of LEL hydrocarbon mixtures and to minimize the level of oxygen in a defined space. Nitrogen is also applied to prevent oxygen and/or moisture from coming into contact with reactive or adsorptive products.



The basic requirement for a successful and safe purging operation is knowledge of the principles concerning the formation and control of gas mixtures. Additional requirements include a thorough knowledge of the application of these principles for each situation; a well-prepared procedure detailing the sequence of events; a predetermined rate of introduction of the purge medium; and verification of endpoints. Finally, the steps of the procedure must be followed and carried out by capable, well-trained and competent personnel.

DISPLACEMENT AND DILUTION

The replacement of one gas by another in an enclosed space takes place by means of two distinct actions – displacement and dilution – and hence, there are different methods used in the purging process.

1. **Displacement Purging -** In displacement purging, inert gas is injected into an open apparatus to displace a dangerous or harmful gas. A slow flow rate of nitrogen gas is normally maintained; this method is used primarily when the height to diameter ratio of a container is high. The inert gas should ideally have a higher density than the gas to be displaced. STEP will normally provide the nitrogen in liquid state in a tanker. The liquid nitrogen is vaporized in a latent heat or direct fired evaporator, and the gaseous nitrogen is then injected

into the vessel as a controlled rate and pressure. The nitrogen squeezes the atmosphere out of the vessel via the exhaust vent valve.

2. Dilution Purging - Dilution purging involves injecting an inert gas to lower the concentration of a harmful or dangerous gas. This method is used when the vessel has a lower height to diameter ratio. The best way to achieve good mixing is to have wide spacing between the inlet and outlet ports and ideally the inert gas should have similar density to the harmful gas. Dilution purging should not be used if there is dead space in the vessel, because this space cannot normally be reached by the inert gas. The diluted gas, composed of the harmful gas and nitrogen is then discharged and further processed.

Certain conditions, such as the size or shape of the vessel or the nature of the gases, cause the purge gas to mix with the original contents so that the purge tends to proceed by dilution. Purging by dilution can be accomplished in situations by alternately pressurizing and depressurizing the facility. To accomplish a satisfactory purge by dilution or mixing requires a volume of inert purge gas that may be several times the volume of the free space of the vessel being purged. This occurs because as the purging proceeds, increasing amounts of purge gas are lost from the vents in mixture with original contents.

Almost all purging operations are combinations of displacement and dilution actions. In actual practice it is impossible to avoid some mixing of the purge gas with the gas that is being replaced but, in general, the less the mixing or dilution, the more efficient the purge. Purging without the use of an inert medium such as nitrogen gas should not be undertaken.

CAUSES OF DILUTION OR MIXING

The factors affecting the relative proportions of displacement and mixing action in a purge should be understood so that careful attention can be given to avoiding or minimizing those factors or conditions which promote mixing.

Some of the more important causes of mixing during a purge include:

1. A large area of contact, promoting natural diffusion.
2. A long period of contact, permitting natural diffusion.
3. Agitation resulting from a high input velocity.
4. Gravitational effects resulting from introduction of a heavy gas over a light gas or a light gas under a heavy gas.
5. Temperature changes and differentials causing convection currents.

Failure to recognize the importance of process vessel design such as the location of the purge gas input connection, the rate of input of the purge gas, or temperature differentials, can result in a purging operation being higher percent dilution and only a very low percent displacement.

AREA OF CONTACT

There is always some diffusion of the purge gas into the original gas, and of the latter into the purge gas at the surface of contact. The amount of mixing which results from diffusion is dependent upon contact. The area of contact between the purge gas and the original contents is dependent on the size, shape and internal construction of the chamber being purged. Ordinarily, little can be done to limit the mixing resulting from this factor. Nevertheless, contact area has a very great effect on the efficiency of a purge.

For example, when purging a tall, narrow tower, the area of contact between the gases is small compared to their volumes. Mixing is limited and the quantity of inert purge gas used may not be much greater than the volume of gas or air to be cleared out. The crown of a storage holder, in contrast, is a flat, shallow dome, having a height significantly less than the diameter. It is impossible to avoid having a large area of contact in a chamber of this shape. Consequently, it is usually necessary to use at least several volumes of inert gas per volume of free space in purging.

When purging process pipe, the area of contact may be so small that little mixing will occur. Advantage can be taken of this condition to conduct an inert purge by use of a quantity of inert gas that is only a fraction of the volume of combustible gas or air to be replaced. It is possible to introduce just enough inert gas to form a "slug" or piston between the original gas content and the entering gas. This slug and the original gas ahead of it, is pushed along the pipe to the end of the section being purged by the gas introduced after it.

TIME OF CONTACT

The duration of contact of the surfaces of the purge gas and the original gas or air should be as short as possible. Excessive mixing by natural diffusion will result if the purge gas input rate is too low. Interruptions and variations of the purge gas input rate should be avoided.

INPUT VELOCITIES

The velocity of the entrance of the purge gas has an important effect on the nature of the purge. As a rule, the size of the purge gas inlet to containers other than pipe should be as large as practical, so that the input velocity is very low. This keeps agitation or stirring of the chamber contents at a minimum. If the purge gas input connection is small relative to the rate of input, the velocity of the purge gas may carry it to the center or across the chamber, resulting in mixing.

When the only available input connection is relatively small, it is best to use a low rate of input to attain purging by displacement over a longer duration rather than purging by dilution. If the input velocity is high and the outlet vent is large, the purge gas may stream or arc across from the inlet to the outlet, limiting both displacement and dilution.

STEP Energy Services – Nitrogen Treatment of a Large-Scale Gas Facility

STEP recently executed the successful nitrogen purge and oxygen-free start-up of a large scale, sour gas facility. Success of the project began with early engineering and planning with the client to clearly define and understand the processes being affected, analyze the characteristics of the gas, and define the end point of the treatment. Careful attention was given to worker safety during the purge process by minimizing the number of nitrogen injection points, venting the facility through proper discharge stacks and vents, and organizing the logistics of nitrogen delivery so as not to interfere with on-going work.

Of importance to the successful treatment was the analysis and characterization of the gas to be purged from the facility. While nitrogen gas is well understood regarding its effect to inert process facilities, consideration needed to be given to the various process vessel sizes and interconnecting piping; the varying velocity effect and gravity effect of nitrogen gas as it traversed the process needed to be well studied and understood to provide assurance of a complete and effective purge of hydrocarbons. Characterization of the facility gas being purged allowed STEP to understand the change in gas composition and its parameters – specifically, the LEL and UEL (Upper Explosion Limit) - as the purge progressed.

To assist in the timely removal of hydrocarbons from the purge out of service, STEP factored hot nitrogen to increase the rate of vaporization in segments of the process where liquid hydrocarbons were likely to reside. Stripping of hydrocarbons at elevated temperature required a thorough review of materials in the facility and limits of thermal effect such as heating rate and maximum temperature.

STEP recognized the potential for "shadow" zones within the process where LELs likely would have persisted due to a lack of turbulence. Understanding that these zones were going to be problematic allowed STEP to work with the client in the development of effective procedures to pressure cycle these areas and induce turbulence for improved vaporization of any remaining hydrocarbons.

After the process facility was LEL-free, maintenance work was performed by the client; significant time was saved by the client employing nitrogen for purge out of service based on previous history. STEP's ability to safely apply high-rate volume hot nitrogen was key to saving the client several days in the initial purge out of service.

Prior to the start-up of the gas facility, STEP utilized ambient temperature nitrogen to reduce the oxygen concentration to an acceptable level in various process vessels. Again, recognizing the potential for shadow zones in each process vessel, this allowed STEP to collaborate with the client in the designed of a series of pressure cycles to create turbulence for adequate mixing and oxygen removal. By using a series of pressure cycles for oxygen removal, the client was also able to simultaneously perform acoustic leak detection on all connections prior to sour gas feed-in.

The nitrogen purging programs engineered by STEP proved to be accurate, and when paired with the execution from field professionals, resulted in significant time savings for the client. Guided by the company's culture of providing an exceptional client experience, STEP was recognized for outstanding safety leadership during the outage, which included care and attention to all activities immediately surrounding the nitrogen operation.