Chapter 19
Purging Air from Piping and Vessels in Hydrocarbon Service

I. General Requirements

A. After motor vehicle accidents and underground excavation accidents, purging air from piping and vessels in hydrocarbon service is the next most dangerous activity undertaken within the oil and gas business.

B. The goal of purging lines and vessels is to:

1. Ensure that an explosive mixture will not form

2. Ensure that no mixture will be exposed to an ignition source

By rigorously striving for both parts of the goal we will significantly reduce the risk of personal injury from the failure to meet just one of the goals (i.e., if an explosive mixture does form, keeping that mixture away from any possible ignition source will still prevent personal injury or property damage).

C. This document is intended to provide guidance as to the necessary elements and options for local purge procedures and it does not substitute for local procedures or local engineering review of those procedures.

II. Definitions

A. *Clearing purge:* Replacement of one substance so rapidly that there is a minimum of mixing, thus reducing the duration of any explosive mixture.

B. *Critical flow:* Whenever pressure downstream of a choke is less than the *critical pressure*, the flow rate of a gas through the choke will be a constant that is dependent upon the upstream pressure and the speed of sound.

C. *Critical Pressure:* The pressure downstream of a choke at which flow changes from critical to sub-critical with increasing downstream pressure. The critical pressure is

$$P_{cf} = P_f \left(\frac{2}{k+1}\right)^{\left(\frac{k}{k-1}\right)}$$

where both pressures are in absolute units and k is the ratio of specific heat at constant pressure to the specific heat at constant volume (k has a value of about 1.3 for methane at 100 psig and 60°F). Generally, critical pressure will be about ½ of upstream pressure.

D. *Dilution purge:* Introduction of enough inert gas to ensure that an explosive mixture cannot form.

E. *Displacement purge:* Replacement of one substance with another without appreciable mixing. Displacement purges are typically done by separating the two substances with an inert fluid or with a mechanical pig.

F. *Lower Explosive Limit (LEL):* The lowest concentration of an explosive gas in air that will support combustion. Methane has a LEL of 5% at atmospheric pressure and 60°F. As pressure or temperature increases, the LEL will decrease.

Note: combustible-gas detectors are calibrated as a percent of LEL, so when the detector registers 100% the concentration is at the LEL for atmospheric pressure and 60°F (or 5% methane by volume).

G. *Upper Explosive Limit (UEL):* The highest concentration of an explosive gas in air that will support combustion. Methane has a LEL of 15% at atmospheric pressure and 60°F. As pressure or temperature increases, the LEL will increase.

H. *Auto-ignition temperature:* The temperature that will cause an explosive mixture to spontaneously ignite. As pressure or temperature increases, the auto-ignition temperature will decrease.

III. Ignition Sources

Since one of the goals of a purge process is to prevent a mixture of gases from contacting an ignition source, any purge procedure must identify possible ignition sources.

A. *Normal sources:* These ignition sources include unclassified electrical equipment, engine exhaust, welding equipment, etc.

B. *Static electricity:* Whenever a mass moves relative to another mass (e.g., stocking feet on a carpet, or gas flow through a pipe) there is a possibility of one of the masses accumulating a static charge. This charge can become significant when long runs of piping are included. If there is a path to allow a built-up charge to pass to ground by arcing, then the arc can be hot enough to ignite an explosive mixture.

C. *Heat of compression:* A high-velocity gas stream will not mix with a static fluid volume within a pipe or vessel. The high-velocity stream will try to compress the static volume against a closed valve or other dead end. This compression will continue until the downstream volume is at a high enough pressure that further flow of the high-velocity stream is impossible. While compressing the static volume its temperature can rise above the auto-ignition temperature of an explosive mixture.

IV. Purging guidelines

A. Clearing Purge

Using produced gas to purge air from piping and vessels is the most common purging activity undertaken in our business. This can be done very safely if the procedure takes into account all of the prerequisites and design considerations below.

1. Prerequisites

a. *Evaluate system volumes:* Clearing purges are most effective for a single straight path from the source to the vent. As a rule of thumb, the sum of the volume of all branches and deadlegs should be less than about 10% the main volume being purged.

b. *Source gas:* Ensure that the source of gas is free of oxygen.

c. *Automated valves:* Ensure that any automated valve in contact with the purge flow (e.g., the dump valve on a separator that is being purged) can be disabled in the position that the purge requires (e.g., remove control pressure from a fail-closed valve that you want to purge against or block open a fail-closed valve that you want to purge through).

d. *Purge monitoring:* Ensure there is a pressure gauge downstream of the valve controlling the purge to ensure that required pressures are maintained.

2. Design Considerations

a. Vents: The placement and size of the flow outlet is critical to a safe purge procedure.

(1) *Number of vents—one:* Having multiple vents open results in an unacceptable chance that the entire purge stream will flow out the first vent and the subsequent vents will ingest air, increasing the risk of an explosion or fire.

(2) *Vent location:* The single vent should be located as close to the dead-end point as possible to minimize the quantity of trapped air in the deadleg between the vent and the last block valve.

(3) *Vent size:* The size of the vent determines the largest pipe or vessel diameter that you can purge at a given pressure. At a purge pressure

of 15 psig, you can purge a 36-inch vessel through a 1-inch valve and a 72-inch vessel through a 2-inch valve. At 200 psig purge pressure the largest line that can be purged through a 1-inch valve is 4 inches, and a 2-inch valve can be used to purge a 24-inch vessel.

b. *Purge pressure:* You are trying to purge a volume of pipework and the purge rate is based on the pressure within the piping. To allow an adequate purge, the purge pressure must be high enough so that you reach critical flow. When venting to atmosphere, any pressure above approximately 15 psig will ensure critical flow. Using purge pressures substantially above 15 psig will require increased purge time and will result in venting excessive quantities of gas to the atmosphere *with no improvement in purge efficiency*.

c. *Purge rate:* The introduction of purge gas should be done at a rate consistent with the flow out the vent so that a constant pressure is maintained in the line. This can be controlled by throttling the source valve open in very small increments to raise the pressure.

Once the purge has started it must continue to completion. Stopping or significantly slowing a purge in progress will result in rapid mixing of the purge gas with the air in the line and can create an explosive mixture.

If the purge must be interrupted, then the line should be blown back down to zero and the purge re-started from step one. If the source valve is open too far and the pressure in the line increases, then you should increase the duration of the purge. Add 10% of the remaining time for each 15 psig above the purge-design pressure (e.g., if you are 10 minutes into a 15-minute purge and the pressure has crept to 30 psig, then the remaining time should be adjusted to 5.5 minutes).

Records of the purge pressure, the time required, and the volume purged should be maintained to satisfy reporting requirements for green-house gas emissions.

d. *Purge time:* Through extensive experimentation, it has been determined that purging 2.5 pipe volumes will provide almost 100% probability that the entire original atmosphere of the pipeworks has been replaced with purge gas. As a practical consideration, it is generally better to round the required purge volume to 3 pipe volumes.

As long as the exhaust pressure is at or below the critical pressure, purge time can be calculated by:

$$t = 3\left(\frac{\sum ID_{seg}^2 L_{seg}}{ID_{vent}^2 v}\right)\left(\frac{P_f T_S Z_S}{P_S T_f Z_f}\right)$$

In most cases, temperature and compressibility at flowing conditions are close enough to temperature and compressibility at standard conditions to drop those terms from the calculation. The vent inside-diameter is the ID of the reduced cross-section in the ball of a reduced-port ball valve, not the ID of the vent piping.

Converting the times from the calculation to minutes yields the following table:

Pipe Size	Vol/1000 (ft^3)	Purge Time (1-inch) per 1,000 ft at 15 psig (minutes)	Purge Time (2-inch) per 1,000 ft at 15 psig (minutes)
2	21.8	0.40	0.10
4	87.3	1.62	0.40
6	196.3	3.64	0.91
8	349.1	6.47	1.62
10	545.4	10.11	2.53
12	785.4	14.56	3.64
16	1,396.3	25.89	6.47
20	2,181.7	40.46	10.11
24	3,141.6	58.26	14.56
30	4,908.7	91.03	22.76

It is unacceptable to rely on explosive-gas detectors to determine when a purge is complete. The fluid dynamics of a critical-flow clearing purge are such that it is normal for the purge gas to bypass considerable volumes of air during the initial phase of the purge. Consequently, you will often see 100% LEL at the vent long before you have completed purging 3 pipe volumes, and a gas detector would tell you to stop the purge before the air has been removed. Further, a stream at 100% LEL may still be below the UEL and be explosive when you stop a purge based on a gas detector.

B. Dilution purge

In a closed, air-filled system at atmospheric pressure, adding enough nitrogen to fill 49% of the pipe volume will ensure that an explosive mixture cannot form (with a 20% safety factor). Because of the physical relationship between pressure, volume, and temperature it is very easy to determine when you have injected 49% of the pipe volume—the pressure (in psia) will increase by 49%. For example, if your atmospheric pressure is 12 psia you can introduce nitrogen to raise the pressure in the line to 18 psia (6 psig) and you will have injected 50% of the pipe volume with the inert gas. Other inert gases can be used, but each has a different dilution rate (e.g., CO_2 will provide proper dilution at 38%).

Dilution purges are very effective when the system configuration has large pipe volumes that would not be swept by a clearing purge. For example, a gathering system with three trunk lines coming together that would require two vents to be open during the purge.

Since injection rates, equilibrium temperature, and product removal are so specific to a given piping configuration, dilution-purge procedures should be developed by engineering personnel each time a dilution purge is considered.

C. Displacement purge

If you can physically separate the air in the system from the explosive gas being introduced, you can reduce the potential for explosion to near zero. The problem with this is ensuring that you have absolutely separated the two gases and that none has leaked past the separating media. You can use a slug of inert gas, a slug of liquid, or pigs to isolate the gases. With inert gas or liquid you are relying on very high gas velocity to minimize mixing, and the high velocities bring with them a risk of the explosive gas bypassing the slug and compressing the air to auto-ignition temperatures. With pigs, you will generate a large static charge from the pig moving through the piping, and any bypassed explosive gas could be ignited. Displacement purges are seldom the best choice.

IV. Conclusions

A. Always assume that an ignition source is present and develop procedures to address possible ignition sources.

B. The key to a safe purge is control. Manual valves should be exercised to ensure that they are not frozen. Automated valves should be disabled and/or blocked in a known position.

C. The source of purge gas should be verified to be oxygen free.

D. It is reasonable to develop standard clearing-purge procedures for frequent operations (e.g., purging a meter run, or purging a well site). Infrequent tasks, dilution purges, or displacement purges should be designed for each specific job, and engineering participation in the development of those procedures should be encouraged.

E. The procedure should specify opening one vent. the vent should be at least 1-inch nominal, and it should be located as near the end of the purged piping as possible. Under no circumstances should more than one vent valve be open.

F. Pressure on the line being purged with a clearing purge should kept be as low as possible while still high enough to provide critical flow out the vent.

G. Once a clearing purge has started, do not stop (or significantly slow) the introduction of gas until the purge is complete. If pressure on the line increases during the purge time, then increase the remaining purge time 10% for each 15 psig increase in pressure.

V. Nomenclature

P_{cf}	Critical flow pressure (psia)
P_f	Upstream flowing pressure (psia)
k	Ratio of specific heats (c_p/c_v)
t	purge time (seconds)
ID_{seg}	Inside diameter of piping in a segment (inches)
L_{seg}	Length of a constant-ID segment (feet)
ID_{vent}	Inside diameter of vent valve (inches)
v	Gas velocity (critical velocity of methane is 1,315 ft/sec)
P_S	Standard pressure (14.73 psia)
T_S	Standard temperature (60°F or 520R)
T_f	Flowing temperature (R)
Z_s	Gas compressibility at standard temperature and pressure
Z_f	Gas compressibility at flowing conditions