SAMPLING 3-PHASE FLUIDS (GAS, HYDROCARBON LIQUID, AND WATER) FOR QUALITY DETERMINATION

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The proper sampling of a 3-phase stream, like measurement, is decidedly more difficult than most engineers and operations people think. In order for this important step in the measurement process to be accomplished properly, the rules of sampling must be followed to the letter.

In order to know what is coming from a produced well, the oil industry is developing the technology to measure 3-phase flow.

To enhance this 3-phase meter, a sampling system has been developed to accurately sample 3-phase flowing streams.

Much study has been involved in the operation of sampling condensate in the Gulf of Mexico, as well as LP and gasoline streams. Both LPG and condensate are streams that have light ends, light liquid hydrocarbons, and water.

The systems that were developed for LPG, gasoline, and condensate years ago were not truly designed to collect a true, representative sample of the total stream. At that time, the systems were looking for hydrocarbons only. Now, however, the importance of the sample being representative of the total stream cannot be overstated.

The total stream includes gas, both hydrocarbon and inert gases, liquid hydrocarbons, and water and particulates. The gas portion of the stream will be gas phase and gas in solution. Considering the ramifications of the sample and its' composition on payment and balance, this mixture of products must be homogeneous at the sample point.

The first consideration is where to take the sample in the line. In order for a sample to be drawn that is representative and repeatable, the line must have enough turbulence to ensure homogeneity of all the products and contaminants. The droplet size should be small enough to allow this uniform mixture to be evenly distributed across the full face of the line.

Since existing facilities are not designed specifically to sample multi-phase streams, the following is an outline of the minimum requirements to perform this task:

1. The system must be equipped with a back pressure control valve that will ensure the multi-phases will be as close to a single phase as possible. This, of course, is as important for measurement as it is for an accurate sample.

2. The line must be conditioned. The proper conditioning of the line may not be done with pumps, strainers, meters, piping, manifolds, or velocity. Velocity alone, or simply changing direction from horizontal to vertical, cannot be expected to cause the proper conditioning of the line at the sample point. As the liquids are moving through a line around an elbow or through a tee, a swirling action or "barber pole" effect might be expected. This centrifugal action will spin the heavier contaminants or components in the line to the outer walls of the lines. The product at the sample point must be a homogeneous mixture. A static mixer specifically designed for your product and flowing conditions is a requirement.

What is proper line conditioning? Proper dispersion and distribution of all the components across the face of the line is the only criteria of adequate mixing in the line. This is small droplets evenly distributed. Small droplets must be described as a droplet that may be captured in a sampling device and pumped from the line to become part of the captured sample (composite). The droplets of the contaminants may not be expected to turn a corner and move out an opening or probe as easily as the general products in the stream.

Laminar or stratified flow: This may be single, double, or even triple layer flow, with the lighter on the top and the heavier on the bottom. This laminar flow is to be expected at flow rates below 4 to 6 feet per second, but may occur even at elevated rates above 6 to 8 feet per second. Velocity, along with elevated Reynolds numbers, will not create adequate dispersion and distribution for sampling.

Dynamic versus Static Mixing:

Dynamic mixing occurs in a line when some type of mechanical device is inserted into the line, or a portion of the stream is drawn out of the line, conditioned, and pumped back into the line through some arrangement of nozzles. There are numerous dynamic styles of mixers available for consideration. Whether or not they are going to create adequate mixing upstream of the sample point is the question the user must ask. Can this stream be proven? Does the streamlining effect of higher velocity have an adverse affect on the dynamic mixing system? This should be properly addressed.

Static mixing is done by building a pressure drop into the pipeline upstream of the sample point (2-4D, no more). A static mixer should be designed to create the dispersion and distribution desired without creating excessive pressure drop. The properly designed static mixer will do this over ranges from 1.5 feet per second and above. If very low flow rates are expected, this information must be passed on to the supplier.

The sampler spool will have the mixer installed with the sample point two pipe diameters downstream of the mixer. The sampler will be installed in a horizontal plane, so the products will flow down and out to the sample container.

3. The sample pump must be designed specifically for the purpose of "grabbing" the sample and pumping that sample from the line regardless of flowing conditions (pressure or temperature) or product properties (viscosity, particulate content, or vapor pressure).

The isokinetic sample probe is designed specifically to trap a sample from the flowing stream and pump that sample into the container.

The sample pump must be designed in a way that will not inhibit the mixed sample from moving freely into the sample head; i.e., inlet check valve. The inlet check valve will cause the mixed sample to separate and the sample pump will vapor lock.

The inlet to the sample collection head should be large enough to inhibit the diversion of sample droplets. The sample head should be self-purging between strokes.

The sampling device must be designed to allow the passage of sand, dirt, pipe debris, or filings that may be in the flowing stream. The sampler must be designed to pump the water and sediment by the check valves, regardless of wax content, viscosity, or pressures.

Since the sample container is normally going to have pressure higher than pipeline pressure on the piston above the product, the sampler must work independently of any associated conditions.

The sampler should be designed to pump all of the trapped sample into the container. Any product retained in the collection head because of clearances from pistons or inlet check valves will most certainly be heavier contaminants, such as water in natural gasoline, debris, or wax.

TIMING OF THE SYSTEM

The multi-phase sampling system, as with all liquid sampling systems, must be actuated proportional to the flowing stream. In order for the components in the sample container to be related to a specific volume of total products moving through the pipeline, the sampling system must be interfaced with the flow.

SAMPLE CONTAINER

There are two types of sample containers in use today.

1. Standard open or atmospheric type container.

This container is equipped with gas pressure or Nitrogen to maintain a pressure head on the product pumped into that container.

The container is equipped with a circulating pump and piping to mix the sample after the composite is collected and ready for conditioning.

It is incorrect to assume that the gas blanket on top of the sample in a sample container will keep the light ends in the liquid phase. Each gas component will seek its own vapor pressure in the head space, allowing the sample to change, which will ultimately change the density and/or API gravity.

2. Constant Pressure Product Container.

The newest method of storing the collected sample is to employ a container that has a sliding piston. The use of the constant pressure sample container allows the sample to be stored and mixed without changing phase.

To retain a collected sample in the same phase as it is in the pipeline, the light ends must be kept as part of the sample. If the light ends are retained, the API gravity and specific gravity will not change.

To use the Constant Pressure Product Container (CPPC) as the sample container, the sampler will be required to capture the sample and pump that collected bite through the tubing and into the cylinder. The cylinder has a precharge gas on the back side of the piston to keep the sample in a single phase. The precharge gas is 50 to 100 psi above the pipeline pressure.

To mix the contents of the CPPC, the valves are opened and the sample is pushed into the mixing piping. The piston will move as the product flows into the mixing piping, keeping the product in a single phase. The mixing manifold includes a circulation pump that is turned on and the sample is circulated through the mixing system.

The sample mixing time is of the utmost importance. The mixing time should be determined for each type of crude or product that is expected, as required by API Chapters 8 and 10.

In order for the sample to be accurately analyzed, it must be kept in the same phase during collection and storage as in the pipeline.

The sample must be collected, stored, and transported in containers specifically designed for this function.

The transportable Constant Pressure (CP) sample container that is used must be capable of the phase control and must have the mixing capability to re-mix the contents of the container to a completely homogeneous mixture, and be D.O.T. Approved.

With gas, water, and hydrocarbon mixtures, the continued mixing of the contents during sample transfer from stationary container to transportation container or container into analytical devices or glassware cannot be stressed enough. These techniques are covered in the latter pages of this paper.

SAMPLE DRAW FROM STATIONARY CONSTANT PRESSURE SAMPLE CONTAINER INTO TRANSPORTABLE CONSTANT PRESSURE CYLINDER FOR RVP & LIGHT END RETENTION

The purpose of the sampling system is to collect a composite sample of a parcel moving through a pipeline or into a truck, tank car, barge, or ship.

Most samples today are taken to ensure product quality. This includes API gravity determination and a chromatographic analysis. The chromatograph will characterize the components from the lights (Butanes) to the heaviest component (1,2,4 - Trimethylbenzene). The only sampling method that can guarantee the accuracy of this analysis is the constant pressure cylinder method.

The sample pump takes the bite of sample and pumps that sample into the constant pressure cylinder for storage. At the end of the parcel or delivery, the composite sample that has been collected in the cylinder must be mixed and transferred to appropriate containers for transportation to a lab for analysis and retention.

The steps for sample transfer are:

If the sample container is equipped with a mixer, attach the mixing handle to the mixing rod and move the mixer through the product 3 to 5 times smartly (not violently). This will ensure the collected sample is homogeneous prior to the transfer. **NOTE**: If water and particulates are contaminants, the mixing is much more important. Mixing must be continued during purge and transferred to a transportation cylinder.

For the API gravity and further analysis on the sample, a transportable constant pressure cylinder should be used.

Proper handling is required for accurate results.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.