

Title: Light Hydrocarbon Measurement by E.L. Upp

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by

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Introduction

Light hydrocarbons; roughly, pentanes and lighter in the hydrocarbon chain, have become a more popular feedstock for the chemical industries. Sufficient demand has generated international trading in these fluids. This has created a need to re-examine our measurement practices, since at the same time the value of the product and the need for accurate measurement at much wider transfer conditions has increased. A discussion of the latest practices in the measurement of these products considering these requirements, is the subject of this paper.

Background

For years, the lighter hydrocarbons were more of a pain to the gas producer than the value received for them. With the development of new polymerization processes and the wider use of the light hydrocarbons, their value changed from one of heating fuels to feedstock's for the chemical industries. This was accompanied by an increase in their value in the marketplace. As with any product in the marketplace, if there is little economic value then there is little demand for accurate measurement. There is considerable demand for this knowledge of proper measurement today as is evidenced by the preparation of two standards: GPA, Tentative Standard 8181-81; Mass Measurement of Natural Gas Liquids; and API, Manual of Petroleum Measurement Standards, Chapter 14, Section 8, Liquefied Petroleum Gas Measurement. Both of these have been prepared in the last five years.

The Fluid Definition Problem

The basic flow measurement problem is one of the definition of the fluid's transport characteristics which allows a measurement to be made at line conditions and through proper correction factors reduced to base or contract conditions. The reliability and acceptance of the data available to do this is the major question.

For many years, the light hydrocarbon products were relatively pure propanes and heaviers, which we handled at ambient temperatures and relatively low pressure (100 to 200 psig). The available correction data was based on 30oF and higher temperature test data, with little concern for compressibility effects. This information was printed in the ASTM tables, which covered specific gravity ranges of .5 through 1.1 and was based on three pure products and one mixture. Extrapolations were made from this original data to temperatures much lower than the original data. Handling pressures also increased and required extrapolation. Mixtures that hadn't been handled before such as ethane-propane in variable concentrations became common. As the companies began using the data at these expanded conditions, errors in measurement resulted. This generated interest in tests run on actual fluids by individual companies to determine the applicability of the tables for their particular stations. Considerable work was done by the NBS on pure and commercial grade products that defined the problem of the tables and began to define new data. International movement of these

products by ship introduced new conditions of temperature and atmospheric pressure measurement of flow. We are not to cover this last subject today, but the influence of these conditions on the definition of the problem should not be overlooked. Likewise, lighter mixtures were tested and tables such as GPA TP-1, TP-2 and TP-3 were developed for use by individual companies for products they were handling. Many of these mixtures have shrinkages in the 5 to 10 percent range that were not predictable from one mixture to the next. Likewise, specific gravity of the mixtures were not good keys to their composition and hence the effects of temperature and pressure varied for products with the same specific gravity.

Densitometers

As this was occurring, new metering devices called densitometers became available. They replaced the need for an accurate knowledge for the PVT Relationships with density and could be combined with common meter systems to give a totalized weigh rate of flow or combined with an analysis to give an equivalent volume at a base or contract conditions.

Custody Transfer on Mass

The Chemical Process Industry usually balances their plant operations on a mass basis since their chemical reactions are controlled on the mass components. As parties to a contract, they are prepared to accept mass as a custody transfer measurement.

Flow Meters

In addition to the fluid and its characteristics, new meters based on new technology have become available and are being considered for the basic measurement device. The standard measuring devices themselves (such as orifice, turbine or PD) have increased their applicability with modernized readout systems, improved materials and the availability of small proving systems.

The Solutions to the Problem

There is no solution for the problems of the flow measurements as outlined above, but there are considerations that recommend one or another method for a given set of flow conditions. As an example, the first consideration is the physical properties of the components and the variations in these components in the mixtures to be measured. If there is sufficient change of composition or if the fluid contains large percentages of ethane, then the densitometer is recommended. Agreements must be made with at least a second party to a contract, so that practices and experiences of both parties are considered in the agreement on the meters that are used.

Measurement Tolerances

Any measurement system made will have a tolerance on its results. Unfortunately, in the flow measurement field a number of people will accept "specmanship" numbers as gospel without a definition of the flow measurement problems, a knowledge of their meaning, or what they have to do with the actual measurement results they should expect on a given station. The answers covered in this presentation have been seen in practice to give the best results for the Flow Measurement of Light Hydrocarbons.

Flow Measurement

Flow measurement of the light hydrocarbon liquids may be done either on a volume or a mass basis and with the fluid either flowing or in a static condition. This paper will not cover static measurement.

Volumetric

Volumetric flow measurement is usually preferred to mass measurement by the industry if physical property changes (i.e., pressure, temperature, volume, composition, compressibility, mixture laws, vapor pressure, etc.) are known, and accepted correction factors can be found that reduce the flowing conditions to base conditions. This decision is mostly a matter of using equipment familiar to the operators.

Mass

Mass determination methods are used where these transport properties change rapidly with time and/or the proper correction factors for the given mixture are not known.

Fluid Requirements

Back Pressure

A meter, whether measuring the fluid in volume or mass units, must be single phase at the meter regardless of the type of meter chosen. Any liquid that is handled close to its vapor pressure should be pumped up to a pressure well above the determined vapor pressure. This requirement is more important as we come down in the mixture range to the lower hydrocarbons (i.e., an 80-20 ethane-propane mix would do well to have 50 psi over the vapor pressure at the point of measurement; whereas an 80-20 butane-propane mix could get by with 10 to 15 psi excess pressure). The API recommends that to accomplish this, a pressure of 1.25 times the equilibrium vapor pressure at the maximum measurement temperature plus two times the pressure drop across the meter at maximum flow rate, be the minimum pressure maintained at the meter. With some of the lighter hydrocarbons, this could calculate as several hundred pounds above the vapor pressure and in these cases the calculated pressure should be adjusted to 50 pounds above the vapor pressure, otherwise excessive pressure will be required and needless pressurizing indicated.

We have become accustomed to thinking of liquids as non-compressible and having a low thermal expansion coefficient; however, with the light hydrocarbon flow measurement, these factors are significant in correcting to a base condition in addition to the importance of properly designing a station to minimize these effects (i.e., insulating meter stations and minimizing pressure drop between a meter and a prover).

Flow Pattern

The fluid, as it enters most meters, should be straight-line turbulent flow, which can be accomplished by the use of straightening devices or a long upstream straight pipe as required by the meter standards. If anything, these lengths of straight pipe for light hydrocarbon fluids are not long enough in the sizes 6-inch and above, and in these cases, experience would always recommend the use of the straightening vanes.

Temperatures

Temperature is an important correction factor for the lighter hydrocarbons. As an example, a 1oF change or error in the temperature may reflect 3/10 percent difference in the calculated volume on the light hydrocarbon streams. Provision for accurate temperature measurement is much more important than usually. This

includes proper insulation, shading, minimizing thermowell effects of conduction and radiation, proper choice of the temperature device's range and sensitivity as well as proper installation for testing.

Compressibility

For relatively constant pressure on the heavier hydrocarbons, the compressibility effects are not that important. Roughly, if the Absolute Flowing Temperature is less than 70% of the Absolute Critical Temperature of the mixture, the compressibility factors are negligible at 300 psig and less operating pressure. However, as we get to the lighter hydrocarbons and higher pressures, the ability of the pressure measurement from which corrections for compressibility are made become critical to accurate flow measurement.

Composition

Variations in composition make the problem of predicting the temperature and pressure effects much more complex, since no one mixture law predicts these effects with variable components as found in raw mix streams, at least not one that has industry acceptance.

Density

The density of the fluid (which replaces the temperature, pressure, specific gravity [composition] and compressibility measurements) is critical as outlined in the discussion of these terms separately. The measured density for flow should reflect the density at one point of measurement in the meter (i.e., in the plane of the orifice, at the rotor of a turbine and in the displacement chambers of a positive displacement meter). Since a device cannot be installed in these locations without disrupting the operation of the meter, provisions must be made to assure that the same conditions exist at the point of sampling. Once again, for the heavier hydrocarbons which have relatively minor density changes with these changes in measured variables, this is not as significant as with the lighter hydrocarbons, which in most cases will require special provision to assure the proper density of the fluid is available for the density measuring device.

Sampling

In most cases of light hydrocarbon flow measurement (with the possible exception of pure products), sampling of the flowing fluid will be required for measurement or quality control of the fluid. It goes without saying to those of you who have worked in these areas that the proper sampling of these fluids is an art unto itself and hence would be difficult to cover in this paper. It is necessary to note, however, that sampling is as important in these flow measurements as is the choice of the meter itself for obtaining accuracy. As an example, the method of testing a densitometer requires sampling into a pycnometer, which is very difficult to do correctly. Likewise, many contracts are written on variable prices for the components, so a mixture breakdown determined by analysis is a part of the final calculation for custody settlement. There are several recent publications by the GPA and the API that have been written on this subject and you are referenced to them for more detailed information.

Volumetric Flow Measurement

Three basic types of meters have been used for the majority of light hydrocarbon flow measurements; the orifice, the positive displacement and the turbine. Some newer devices have been used to a limited degree, but will not be covered here because of their relatively small percentage of usage at this time. However, as time goes by, more of these will be proven useful.

Orifice Meter

The orifice meter has been the workhorse in years gone by for the production field measurement of light hydrocarbon liquids. By installing and operating stations based on standards such as GPA Engineering Data Book, AGA Gas Measurement Committee Report No. 3 and Principles and Practice of Flow Meter Engineering, adequate field measurement (i.e., 3 to 5%) was obtained. Assumptions as to variations in flows, specific gravities and the applicability of compressibility factors were made more for simplicity's sake rather than accuracy. For rough well production measurement (i.e., dumping separators, lack of temperature measurement, spot sampling of composition, etc.), these installations have continued to be used.

For pipeline and plant measurements where 92 flows are more constant, the orifice is used in conjunction with proper sampling, specific gravity, density devices and/or fractional analysis equipment to arrive at a volume at base conditions.

It may be well to describe these systems and some of the terms used, since a number of people get confused when they consider these measurements.

Flowing specific gravity (Note: specific gravity as a term is being replaced by the term "relative density") for liquids is defined as the ratio of the specific weight of the flowing liquid at its flowing conditions (i.e., flowing temperature and flowing pressure) to the weight of an equal volume of water at 60oF. The usual instrument used to measure this value is termed a "liquid gravitometer" reduced to base conditions.

Flowing Density is the pounds per cubic foot of the liquid at flowing conditions. The usual instrument used to measure this is termed a "densitometer".

Note: Some fractional analysis equipment can be made to read out in specific gravity or density. The orifice, to measure volume of fluid at base conditions, requires a specific gravity at flowing conditions, a specific gravity at base conditions, and a differential across the orifice along with some constants based on the physical installation and the measurement contract. To measure volume at flowing conditions, the specific gravity at base conditions is not needed. This system should be limited to fluids in which the compressibility is not appreciable or is known and is usually not used for custody transfer.

To measure volume of liquid with an orifice in conjunction with a densitometer requires a fractional analysis device used in conjunction with a calculation procedure based on the density of each component at base conditions. With the lighter hydrocarbons this procedure is preferred since the temperature effects and compressibility factor are accurately applied.

The Positive Displacement and Turbine Meters

The positive displacement and turbine meters are normally used with the more regularly flowing, clean fluids than those found in the production fields. They are used in conjunction with a prover system (either master meter or mechanical displacement prover) and the flowing volumes are corrected for the effects of temperature and pressure with the added correction of a meter factor based on the proving for volume measurement. This system again would be successful for predictable fluids; however, the densitometer is recommended in conjunction with analytical equipment where the mixture temperature and compressibility correction factors for the fluid are not known.

These prover-meter systems are more costly, and hence are used where the economics of accuracy justify the costs.

Mass Flow Measurement

Mass flow measurement requires only a volume at flowing conditions multiplied times a density at flowing conditions which gives a readout in pounds. As mentioned previously, contracts are being made on this basis. Even though the measurement is exchanged on the mass basis, a statement of line volume is still needed for control and operating purposes, so it is usual to consider some means of determining the volume at line conditions as part of the measurement system even though this number is not involved in the custody transfer.

These mass flow systems are more complex and will require higher-skilled field operating and maintenance personnel than the simple orifice stations. Without proper appreciation of this aspect, the advantages of these systems will not be realized. If anything, the reverse will be true, the manufactures of this equipment can only make the capabilities of accuracy available to the user. The accomplishment of these accuracies are in the hands of the user.

Expected Uncertainty of Systems

It was mentioned earlier that in production fields 3 to 5% balances have been accepted for years. But, as the price of the fluids have gone up, the need to reduce these variances has increased. Likewise, gasoline plants have been working to improve their balances. In an attempt to come up with some guidelines on what the different systems can do for a user, the following numbers are given, recognizing as soon as they are written that they can be proven worthless in given installation or operation. However, these numbers are ones that have been experienced under better circumstances of operation and maintenance.

- Production Measurement without modulating control on separators at wells: +3 to 5% (at best)
- Production Measurement with modulation and/or sufficient storage to allow steady flow, but with proving: +2%.
- Production Measurement with steady flow master meter proving: +1%.
- Production Measurement assumes sufficient higher hydrocarbons to make the PVT relationships predictable.
- Plant Measurement with steady flow and predictable relationships with a prover using computers: +2%.
- With charts these figures should add between +5% and 1% minimum.

The actual plant or field balances obtained may not reflect these individual numbers, since the combination of these numbers for multiple meters is not statistically predictable, but does tend to improve with multiple meters since these meter systems tend to be truly random rather than biased unless some of the foregoing problems discussed are incorrectly evaluated.

Conclusions

We are emphasizing flow measurement of light hydrocarbons because of the large dollars represented by what used to be accepted as adequate measurement. These dollar numbers create interest further up the management ladder as they get larger. Technology has progressed to a degree that will allow us to do a better job provided we are prepared to expend the initial investment dollars and the continuing operating and maintenance dollars.

The successful procedures and equipment to accomplish this have been the subjects of discussion in this paper. There are no patented "best answers" and the decisions on each station should reflect a thorough study of the pertinent factors so that a proper decision will be made.